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Compressed Air

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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"COMPRESSED AIR INFORMATION"

OR

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EDITED BY

W. L. SAUNDERS,

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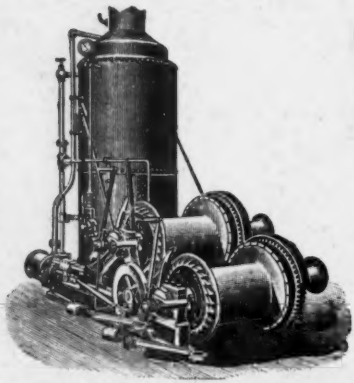

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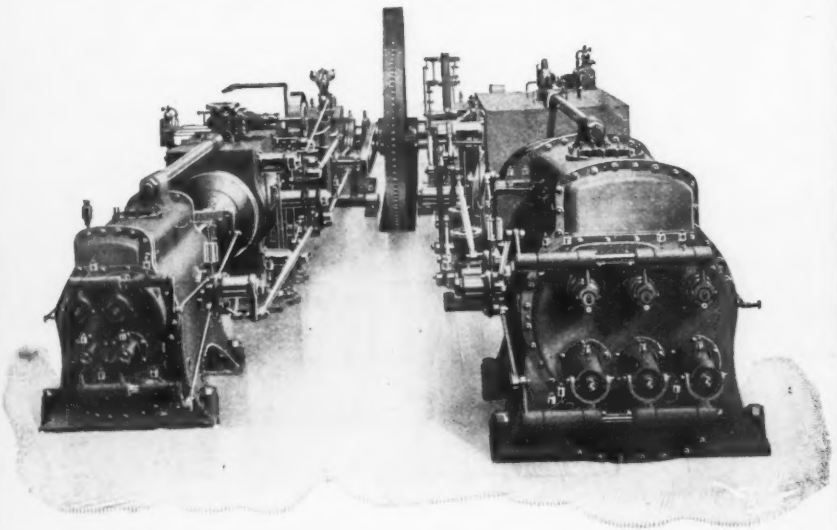

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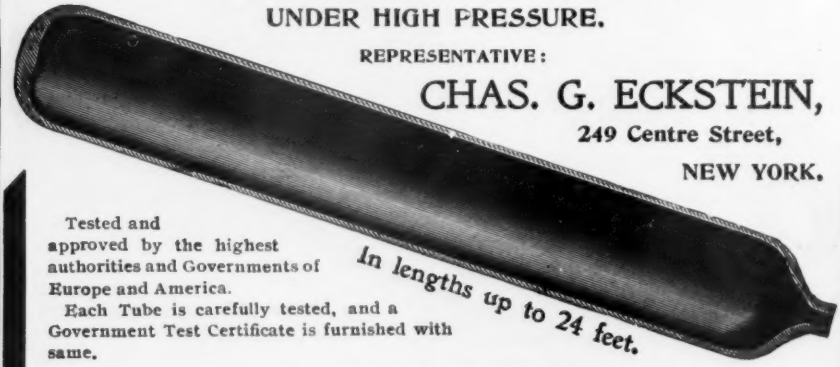

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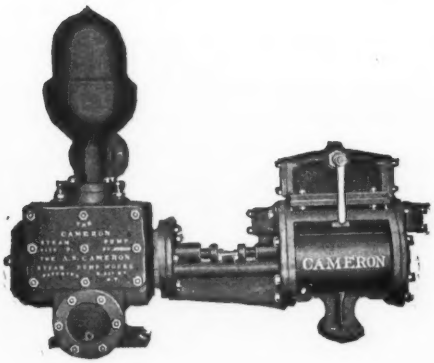

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VOL. VII. FEBRUARY, 1903. NO. 12

Lubrication of Compressors.

COMPRESSED AIR has on various occasions insisted that owners and operators of air compressors do not as a rule give sufficient attention to the question of lubrication.

The subject is one which possesses at the same time interest on the score of economy and also because of the opportunity afforded for accidents.

Elsewhere in this issue we publish a valuable contribution to the subject of compressed air and its production, and while the article is devoted to a discussion of cylinder ratios and the temperatures obtained in compressing to higher pressures, it, at the same time, calls attention to the question of oils and lubrication, which after all is of as great importance as economical compression because improper oil introduces the one dangerous feature of air compression.

That care should be used in selecting a high flash test oil for lubricating the air cylinders of a compressor has long been known, and as positive evidence of this need, we have published from time to time several accounts of explosions, the cause of which can be traced in the majority of cases, directly to the fact that a low grade oil was used for lubrication. Yet in the face of danger and of possible serious accident resulting, it is also as well known that many violations of the above rule are of daily occurrence, and though we believe that it is often due to ignorance, this is hardly a plausable excuse when life is endangered. Every new report of such an accident throws a little more light upon this "not very well understood subject." It is to be regretted that no very accurate data relative to the action of such oils under high pressures and temperatures is known, all values so far determined, such as the flashing and ignition points, being those for atmospheric conditions only. Efforts have been made by some manufacturers to develop high flash test oils, but the difficulty generally met is in the high percentage of carbon contained in these which, for practical results, is about as objectionable as a low flash point. The article which we publish in this issue, gives some very valuable data on the temperatures reached in air compression cylinders, and illustrates the importance attached by at least one of the largest air compressor manufacturers to experimental research along this line. It is hoped that the points brought out will be remembered by users of compressors as well as those engaged in the design of air compressing machinery, for we believe impartial investigation will show that the operator has been at fault in most cases of explosion in compressor cylinders and receivers.

Safe Ratios in Air Compression.

THE DETERMINATION OF THE MAXIMUM RATIO OF COMPRESSION THAT CAN BE USED IN A SINGLE CYLINDER WITH PRACTICAL SAFETY.

In the course of advance in air compressor design, the above question under certain conditions becomes of importance, especially so when the tendency toward higher pressures is considered, an example being in the case of air compressors for furnishing the high pressure air used in pneumatic mine locomotives which sometimes reaches 3,000 pounds per square inch, and in the case of coal mines where the cost of installation of the power plant is of much more importance than that of operation, the fuel used being that which would otherwise be wasted. Any comparatively small loss in the thermal efficiency of the compressor would have far less consideration than the consequent reduction in the cost caused by simplyfying the construction, and for this reason there has been a tendency toward high compression ratios. In the course of certain experimental work carried on by one of the larger compressor manufacturing concerns, namely: The Ingersoll-Sergeant Drill Co., the above question came up and it was decided to carry the experiments further and determine if possible the causes which should limit this, and make deductions sufficiently accurate to be of practical value. For this purpose an experimental air compressor having compound single acting air cylinders of the following dimensions was used. See Figs. 1 and 2.

Low pressure air cylinder, 7″ in diameter by 10″ stroke.

High pressure air cylinder, 1⅞″ diameter by 10″ stroke.

In early stages of this work an explosion occurred which eventually led to the solution of the problem. The compressor was running about 150 R. P. M., against a final discharge pressure of about 1,100 pounds per square inch when the accident occurred, which fortunately was accompanied by no more serious result than the bursting of the receiver and a bad scare for the men working close by, though it had sufficient force to blow the larger part of the receiver, weighing approximately 200 lbs., about 40 feet down the shop. An examination of the ruptured parts left no doubt as to there having been an explosion of much more force than that attributable to the stored energy of the air itself. There were two distinct ruptures.

First: One in the 1″ extra heavy pipe leading to the receiver, which was torn practically into two equal parts having split down the sides for about 9½″ in length, and opened up across the middle over 4″. In this pipe, at the end of the rupture nearest the compressor, an oily residue was found, though only in small quantity.

Second: That of the receiver itself bursting the head to which the inlet and outlet pipes were attached, and blowing the parts in every direction (the body of the receiver being blown down the shop as already stated). Whether flaws in the material of the broken head were in any way responsible for its bursting is doubtful, and difficult to determine, though some signs of defects were in evidence. A carbonaceous oily residue was found in the receiver, there being quite an extensive coating all over the inside of the pipe, and the head which remained intact, while on the broken head there was hardly any residue at all, simply a small quantity of hard, black, dry powder having the appearance of a carbonaceous ash. Neither of these residues showed any life when subjected to the hot flame of a Bunsen burner. Another point to be noted is that the discharge valve and air passages in the high pressure cylinder, were covered with a coating of residue very similar to that (second one) mentioned above, which was found in the burst end of receiver; this also showed similar action when subjected to the hot flame, having no life or burning qualities.

Summary of conditions known to exist at the time of the explosion:

Discharge air pressure.. 1,100 lbs. per sq. in.
Intermediate air pressure ..... 136 lbs. per sq. in.
Intake air pressure.... Atmospheric.
Compression ratio in the H. P. cyl..... 7·384.

The compressor had just previously been running at a discharge pressure approximately 3,000 lbs. per sq. in., and had been running thus for quite some time, during tests, etc., using a lubricating oil of 388° F. flash test. The quantity being in all probability far in excess of the proper or safe amount to use, though no observations as o this were made.

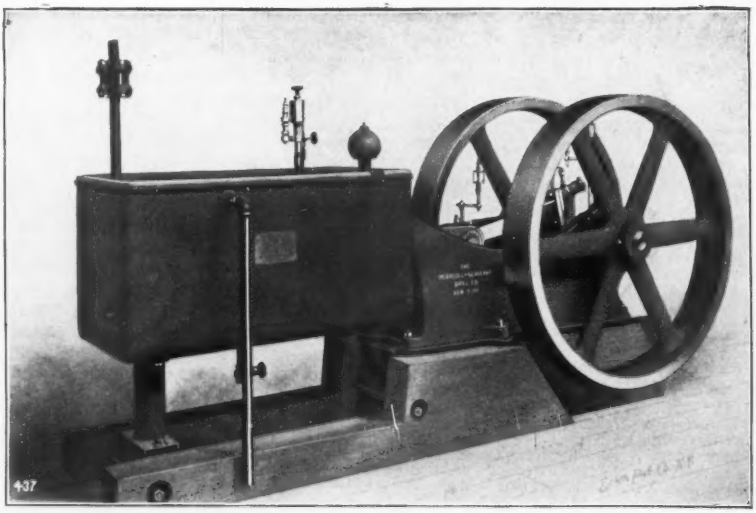


FIG. 1—WATER COOLING BOX IN POSITION.

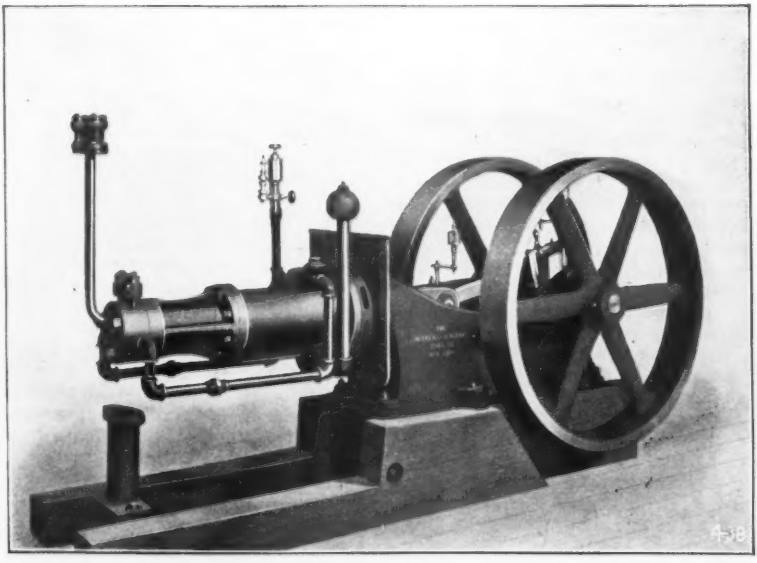


FIG. 2—WATER COOLING BOX REMOVED.

The idea which presented itself at that time in looking for a cause, was that the oil in conjunction with the air must have formed an explosive mixture, which upon being ignited resulted in the accident.

The company supplying the oil was then notified and they immediately sent their expert representative to help throw some light on the subject.

After some consideration of the facts at hand, it was decided to connect up again for running, a new receiver, piping, etc., were supplied, and several test runs made, observations being taken of the different temperatures, etc., as follows:

TABLE I.

No. of Run.	1st.	2nd.	3d.
Speed, r.p.m	150.	150.	120.
H. P. air pressure gauge	1100.	3000.	3000.
Int. air pressure gauge	136.	136.	136.
Intake pressure gauge	Atmospheric.		
H. P. air temperature	148.°F.	325.°F.	194.°F.
Int. air temperature	135.°F.	165.°F.	125.°F.
Intake air temperature	72.°F.	72.°F.	72.°F.

These temperatures were recorded on standard thermometers, that of the low pressure cylinder being placed in a regular cup, inserted in the discharge pipe. For the high pressure observations an improvised cup of asbestos packing was attached on the outside of the discharge pipe.

The first set of these readings it will be noticed, was taken under similar conditions as existed at the time of the accident. The second set maintained the same speed, but the high pressure air pressure was increased to 3,000 lbs. (Note the rise in the high pressure temperature reading.) The third set of conditions was taken at the rated speed of the compressor, and it was while running under these conditions that the special investigation committee arrived. They made a complete examination of the compressor and of the broken parts of the old receiver and piping. The general opinion of the above committee after a long discussion was that much higher temperatures than those recorded by the thermometers were reached in the compressor, and that at these temperatures a gaseous explosive mixture had been formed, which upon being ignited had produced the accident, thus sustaining the first opinion. After these runs were completed, the compressor was taken apart and samples of the oily residue remaining in the cooler tubes and the carbonaceous deposit on the piston and in the high pressure cylinder were taken for further study.

The results of the examination of some of these residues are as follows:

The sample of carbonaceous deposit from the pistons and cylinder was subjected to the heat of the hot plate about 400° F., at which temperature it became a glowing mass. The exact chemical constituents of this last residue are not known, but it appears to contain iron and carbon. However that may be, here appears to be the igniting medium for which several theories had been advanced, such as the piston striking a spark on a small particle of carbon or other hard deposit. Also the effect of excessive friction from defective lubrication in the high pressure cylinder, which could be caused by the oil being gasified in the low pressure cylinder and carried through the high pressure cylinder as a gas having little, if any, lubricating effect, either of which in connection with the aforesaid residue could account for the ignition. At any rate it is probable that some form of ignition is necessary, though no data or results of tests on the flashing of oils under high pressures of air has come under the writer's notice. There is little question as to the increased violence of the burning of oils, etc., under high pressure, experiments carried on by Mr. F. M. Leavitt (M. E.), A. S. M. E., in connection with the development of the automobile torpedo having shown that burning alcohol, etc., in a heater pot in the air flask of a torpedo under 1,500 lbs. pressure, was accompanied by excessively violent and rapid combustion.

Considering the compressor from a theoretical standpoint, assuming that the adiabatic laws of air compression prevail, the temperatures of compression work out as follows:

First Stage of Compression—Low Pressure Cylinder—

Assume atmospheric intake at 70° Fahr., and compressing to 136 lbs. gauge (the intercooler pressure); the temperature of discharge from the low pressure cylinder would be approximately 576° F., and the ratio of compression equal to $151 \div 15$ equal to 10.06 for the low pressure cylinder. This will remain the same for all variations of load since the cylinder ratio is a constant.

Second Stage of Compression—High Pressure Cylinder—

First: Without any intercooling effect being taken into account the intake temperature into the high pressure cylinder being that of the low pressure discharge, viz., equal to 576° F., compressing from 136 lbs. gauge to 1,100 lbs. gauge, the pressure at which the explosion took place, the final discharge temperature would be approximately equal to 1,391° F., and the ratio of compression 1,115÷151 equal to 7.384. Compressing from 136 lbs. gauge to 3,000 lbs. gauge, the rated pressure for the compressor, the final discharge temperature becomes approximately equal to 2,009° F., and the ratio of compression equal to 3,015÷151 equal to 19.96.

Second: With cooling in intercooler down to 70° F., or that of the intake to the low pressure cylinder, this is approximately correct though no exact determination has been made.

Compressing from 136 lbs. to 1,100 lbs. gauge, the final temperature becomes approximately equal to 487° F., ratio of compression as before 7.382. Compressing from 136 lbs. gauge to 3,000 lbs. gauge the final temperature becomes approximately equal to 804° F., ratio of compression as before, 19.96.

No effect on the high temperature point as effected by the cylinder jackets has been taken into account, as any information of value on this point must be determined experimentally for the compressor in question.

Considering the difference between these theoretical temperatures and those heretofore observed, with the opinion prevailing that a pretty high temperature must have been reached, the writer was instructed to carry the experiments far enough to determine if possible the actual temperatures existing. It was then suggested that by inserting small particles of different metals having melting points from 450° F. upwards, into the clearance spaces of the cylinders, and observing the effects on the same, that the highest temperature point could be approximately located. This suggestion relieved the situation considerably, as it was known that the highest temperature lasted only for an instant during each revolution, the cylinder cooling down from the combined effects of the re-expansion of the air in the clearance spaces, and the in-rush of comparatively cold intake air, consequently any thermometric method other than the above which would be able to record this temperature would necessitate considerable delay to install and probably give no more accurate results. The high pressure cylinder head was then fitted with a suitable test plug entering the clearance space, to which were attached the metals used. The preparation of these metals so that they would show the effects of the highest temperature necessitated their being hammered into very thin filaments, approximately 1/1,000 of an inch in thickness, so that the heat could make an impression on them and not be absorbed and conducted away faster than it was supplied. These were arranged in the form of a small semi-spherical rosette, presenting many thin filaments to the air during its passing in and out of the cylinder.

The following are the conditions of running and the results obtained in the high pressure cylinder, no experiments having as yet been tried in the low pressure cylinder.

TABLE II.

No. of Run.	1st.	2nd.	3d.	4th.
Metal used	Tin.	Lead	Zinc	Zinc.
Range of melting temperatures	442.° —446.°	608.° —618.°	725.° —780.°	725.° —780.°
Speed, r.p.m	102.	100.	102.	126.
Time of Run. Min.	15.	15.	15.	25.
H. P. air pressure guage	2250.	2930.	3000.	3000.
Int. air pressure guage	136.	136.	136.	136.
Intake air pressure guage	Atmospheric.			
Temp. observed on H. P. pipe	185.°F.	195.°F.	184.°F.	232.°F.
Temp. observed on Int. pipe	220.°F.	234.°F.	236.°F.	220.°F.
Intake air temp	71.°F.	70.°F.	72.°F.	70.°F.
Compression, ratio H. P	15.	19.5	19.96	19.96
Compression, ratio L. P.	10.06	10 06	10.06	10.06
Effect on test metal	Melted.	Melted.	Ox'dzd.	Melted.

No attempt has been made to carry these experiments further, as a suitable metal or alloy having a melting point under the theoretical temperature of compression in this cylinder, viz., 804° F., is lacking, which temperature cannot be exceeded when compressor is working properly.

These experiments with the results obtained form a basis from which a reasonable solution as to the causes which resulted in the explosion can be derived.

It has been shown that the water jackets had little effect on the air in the cylinder

during the compression, in consequence of which the actual temperatures reached were very near those figured for adiabetic compression. Considering this in a compressor, which is a striking example of excessive cooling properties, the question arises as to what limit must be placed on the number of compressions allowable in a single cylinder, when the lubricant to be used must be selected from the lists of high grade marketable oils prepared for this purpose.

The United States Navy Department, among other requirements for high pressure air compressors for torpedo boats, includes this; that oil shall not be used as a lubricant in the air cylinders, a mixture of soap and water being substituted.

Following the course of the oil as it passes through the compressor, it is found to come in contact with the successive changes of pressure and temperature summarized below:

First: In the low pressure cylinder a temperature variation from 70° F., to approximately 525° F., accompanied by a pressure variation from atmospheric to 136 lbs., this latter pressure and the high temperature lasting 5 per cent. of each revolution (the discharge period).

As the flash point of the oil in question is 383° F., it is evident that considerable volatilization of the same might occur in this cylinder, and so make a thorough mixture of oil and air and whatever moisture accompanies the air. Now passing into the cooler tubes its temperature is reduced to about 70° F., where some of the oil and water is condensed, coming down in the mixed form of residue already mentioned, which in turn is carried over into the high pressure cylinder, where a pressure variation from 136 lbs. to 3,000 lbs. and a consequent temperature variation from 70° F. to 750° F., occurs every revolution. The discharge period, or that during which the high pressure and temperature exist, being only 2.9 per cent. of each revolution, which at a speed of 120 R. P. M. is .00725 part of a second. It is probable that at this point the ignition occurred which upon reaching the discharge pipe and receiver resulted in the accident, as much of the explosive gas already generated was stored in these places.

The high temperature of discharge in this cylinder is sufficient to account for a gaseous oil and air mixture being continuously generated when running up to pressure.

And in view of the fact, that the sample of the carbonaceous deposit from the high pressure cylinder became a glowing mass at a temperature about 400° F., there seems to be at hand all the necessary adjuncts for an explosion, provided that just the right mixture of air and oil is developed. Professor J. E. Denton in a statement on this point cited some experiments in which gasoline and air under atmospheric conditions were mixed in a closed receptacle in which an electric spark was passed. The results were as follows: When the mixture consisted of 8 milligrammes of gasoline and 2 quarts of air, a violent explosion occurred when sparked, but with a mixture containing one milligramme more or less than the above it simply burned or showed no effect at all.

A similar set of conditions probably exists for all volatile oils, when the necessary temperatures are reached, and the correct mixture is formed. The fact that the mixture to be explosive must not vary except within very narrow limits, and that this mixture is seldom approached in general compressor running, is without doubt the reason that so few explosions of this sort are recorded.

In attempting to answer the question under consideration, that as to what limit should be placed on the number of compressions allowable in a single cylinder, it appears at present to depend on the grade of oil used for lubrication, and if the manufacturers of the same could guarantee to furnish an oil for use in air cylinders, whose flash point exceeded a certain temperature, determined and agreed on after careful experiments, or some other form of lubricant, possibly of a parafine or glycerine nature, is forthcoming to take the place, it is useless to adopt any set limit no matter how low, for there are at present a great many if not a large majority of the compressors running using oils whose flash points are far below the temperatures reached in the cylinders, and quite often crude petroleum from which explosive gases are generated under atmospheric conditions will be found in the cups.

Considering, however, that the highest flash oils sold at present will be used, this would mean that they would not flash under 475° to 500° F.; although claims are

made for certain oils having flash tests around 550° F., it is questionable whether at all times they could be unfailingly relied on for this. Taking the former figures as the safer, it would appear that the number of compressions in one cylinder should never exceed (eight), giving a theoretical final temperature when compressing from atmosphere at 70° F. = of 510° F., and in compound compressors (seven) in the high pressure cylinder is a safer figure since intercooling down to 70° F., is counted on, and in many cases this cannot be accomplished (lack of water, etc., being among the conditions which are to be met).

Considering the tendency at present towards higher pressures in both steam and air and the increased cost to purchaser when higher multiple compressors are used, it is to be hoped that experiments for determining the best form of lubricant for use under high pressures and temperatures will be carried on until a successful and determinative issue results.

FRED. V. D. LONGACRE, M. E.

Continuous Power.

The *New York Herald* of January 25th, illustrated and described the new invention of Mr. J. F. Place, for the production of what he aptly terms "Continuous Power." The article referred to touched but lightly on the technical points of the invention, and we give below some extracts from Mr. Place's treatise on the subject.*

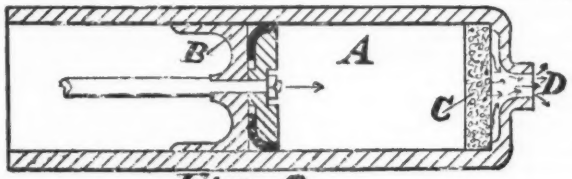


Fig. 2.

"It is a law of physics that whenever any gas, which exists as a gas at ordinary temperatures, is caused to become liquefied, then such liquid gas is, so long as it remains a liquid, at a lower temperature (colder) than the atmosphere, and will constantly boil if exposed to ordinary temperatures—or to the normal heat of the atmosphere. These gases, when liquefied, are called liquid gases, as, for example, liquid air; therefore, a liquid gas is a liquid which boils when subjected to the normal temperature of the atmosphere.

"No matter how much heat runs into a liquid, it gets no warmer. For instance, you cannot raise the temperature of boiling water, the pressure being constant, no matter how fierce the fire, so long as there is any water in the boiler; so, also, the heat of the atmosphere will run into liquid air and keep it boiling under pressure, for the temperature of the atmosphere is 70° F. and that of liquid air is 270° below zero at 125 pounds pressure (or 340° colder); and the pressure being constant, you cannot raise the temperature of boiling liquid air or any other liquid gas so long as there is any liquid left in the boiler.

"The loss of heat due to work done by expansion against resistance carries the temperature theoretically far below the liquefying point, which largely neutralizes the latent heat of condensation, which in air is about one-seventh that of steam, and which disappears entirely at the critical temperature; but provision is also made for a sub-cooler or condenser to absorb the latent heat of such expanded exhaust gas remaining unliquefied, but which is at the point of liquefaction.

"In order to properly explain the system I propose, let me illustrate (well known though it may be) the throttled-nozzle method of making liquid air, which is the process adopted by all who have produced it in quantity—Linde, Hampson, Ostergren, Tripler and others.

"Leading up thereto, I will first show the Joule-Thompson experiment with the porous plug. This well-known experiment is illustrated in Fig. 2.

* Continuous Power the Natural Result of Converting Heat into Work in an insulated Expansion Engine at Temperatures below the Normal of the Atmosphere. By J. F. Place. New York: The Standard Power Co., 1903.

"In the cylinder A is shown a piston B; at C is fixed a porous diaphragm or plug through which air is forced by moving forward the piston, but the diaphragm C, being made of porous material, the air passes through the same with difficulty. As the piston B is moved forward in direction of the arrow, the air in the cylinder A is compressed and consequently is heated; and the piston can be moved fast or slow, so as to give the air in the cylinder a greater or less tension, or a uniform pressure if desired, the air meanwhile constantly passing through the porous diaphragm C and expanding as it leaves the same at D. After a predetermined pressure of the air in the cylinder A is reached and its temperature has cooled to that of the surrounding atmosphere, if the piston B is continued to be moved forward then just fast enough to maintain that pressure, there will be no increase of temperature of the air in the cylinder A, and the heat generated by the friction of the air in passing through the porous diaphragm C as the piston moves forward (and which represents the work done in overcoming the resistance of the diaphragm) will in a perfect gas exactly equal the heat absorbed for the work done during the expansion of the air as it passes through or leaves the diaphragm at D; and consequently there should be no change of temperature. There is, however, as is claimed, a slight fall of temperature (air being, as is supposed, an imperfect gas) and which is known as the Joule-Thompson effect.

"By changing the foregoing Fig. 2 a trifle, it will be seen that it is practically the same thing as allowing air to escape (from a reservoir in which a constant pressure is maintained) through a throttled nozzle. For instance—

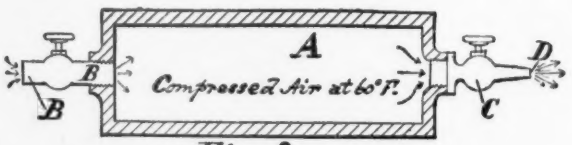


Fig. 3.

"Here A is the cylinder, but instead of a piston a supply pipe B from a compressor or reservoir keeps the air in the cylinder at any uniform predetermined pressure; and, instead of the porous plug or diaphragm shown in Fig. 2, we have in this Fig. 3 the throttled nozzle C delivering at D, by which the air is allowed to escape with difficulty, or is throttled the same as in passing through the porous diaphragm in Fig. 2, so that the pressure in the cylinder A is not lessened, but is kept constant by the supply pipe B from the air compressor or reservoir, and its volume is practically constant. The temperature in the cylinder A is also uniform, the same as the surrounding atmosphere, say, or that of the source of supply (the heat of compression having been removed). The greater the pressure in the cylinder A, the greater will be the friction in passing through the throttled nozzle C, and naturally the greater will be the work of expansion in pushing away the atmosphere in leaving the nozzle; consequently, there will be no change—the temperature of the expanded air at D will be the same as that of the compressed air in the cylinder A. It was long believed that air grew cold as it expanded, but this has been proven to be a fallacy; to be sure it grows cold, and intensely cold, if when it expands it is made to do work; but if no work is done there is no appreciable fall of temperature. This may be easily shown in practice by opening the cock in the compressed-air pipes in any machine shop; the air from the pipes is never even cool, no matter what the pressure may be. But if run through a small engine, and worked expansively by a cut-off valve, the exhaust air is intensely cold.

"The slight fall of temperature, however, owing (if it really exists in practice, as is supposed) to the fact, as claimed, that air is an imperfect gas, and which has been called the Joule-Thompson effect, has been made use of to cool the incoming compressed air in the cylinder A or supply pipe B by passing the expanded air as

fast as it is expanded from the nozzle C, back over the nozzle and supply pipe, as shown in Fig. 4.

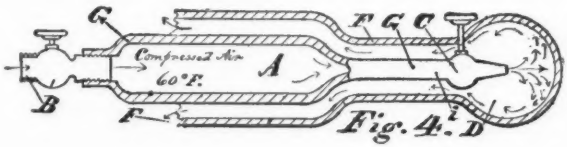


Fig. 4.

"This is the same as Fig. 3, except the expanded air as it leaves the throttled-nozzle C is trapped in the hood or chamber D and the direction of its flow changed, as shown by the arrows, so that it passes back in the outer pipe F (Fig. 4) and is carried back over the inner pipe G in the opposite direction to the flow of the compressed air in that pipe (G). This is the throttled nozzle or regenerative method, so-called, and has been used by all up to this date who have made liquid air in quantity. This method of cooling or production of low temperatures is practically the same as the Siemens' interchanger with the addition of the handicapping device, the nozzle, and it has been known for nearly fifty years. It is crude and wasteful of energy, for, combined with the hood, there is more friction than with the nozzle alone, and the great pressure necessary is costly, not a foot-pound of which is utilized.

"I will here add a rough sketch, shown as Fig. 5, of Prof. Linde's liquid air-making apparatus, which will serve to illustrate also the mechanism of Dr. Hampson and all others who have produced liquid air, and it will be noticed that the method is practically the same as that shown in Fig. 4.

"In this Fig. 5, the throttled nozzle is shown at C, operated by the valve wheel H; the smaller pipe I of the coil shown takes the place of but is practically the same as the cylinder A and pipes B and G of Figs. 3 and 4. This pipe I is supplied with compressed air from the compressor K by the discharge pipe P through the water cooler J and connecting pipe B.

"After the air is expanded from the throttled nozzle C into the chamber D it is passed back over the incoming compressed air supply pipe (I) in the outer pipe F of the coil. The pressure (and practically the volume also) in the pipe I is constant, the nozzle cock C not being opened so wide as to cause a fall of the pressure therein; and the theory claimed is that, however slight the fall of temperature of the expanded air as it leaves the nozzle C, it will absorb a correspondingly small amount of heat from the compressed air in the pipe I, especially from the lower end near the nozzle.

"When the temperature in the chamber D has been reduced to the liquefying point, the liquefied air is gathered in the lower part of the chamber, and is drawn off through a cock as shown. Only about one-twentieth of the air delivered from the nozzle C becomes liquefied, the other nineteen-twentieths passes back through the annular pipe F for the purpose of cooling the incoming compressed air in the pipe I; this unliquefied expanded air is finally delivered to the suction valve of the compressor again through the pipe N. Through the check valve in the pipe O new compressed air is forced from an auxiliary compressor in order to make up for the amount liquefied and drawn from the chamber D.

"The fall of temperature due to the Joule-Thompson effect, as claimed, of the expanded air as it leaves the diaphragm C in Fig. 2 or nozzle C in Fig. 3 has been carefully calculated and amounts to about half a degree Fahrenheit for each drop of one atmosphere of pressure (14.7 pounds). Joule and Thompson (now Lord Kelvin) neither experimented with nor made calculations, so far as I know, for the hooded nozzle with the Siemens' counter-current coil or interchanger (which is the Linde and Hampson method) as shown in Fig. 5. If they had made any such experiments, then we probably should have now before us some calculation as to the effect of the friction in the chamber D, and possibly a new equation entirely for the Joule-

Thompson effect in the nozzle shown in Fig. 4, and perhaps another one for the nozzle with complete interchanger as shown in Fig. 5.

"The figures given as the Joule-Thompson effect from the equation of the authors of the theory by the three authorities, Professors Sloane, Travers and Linde, reduced to Fahrenheit degrees, are respectively .5°, .458° and .497°. Protessor Sloane says that if the compressed air is cooled to 132° F. below zero before it is allowed to escape through the nozzle, then (according to the Joule-Thompson equation) the fall in temperature may be a trifle over one degree Fahrenheit for each atmosphere (14.7 pounds) of pressure released, thus showing that the cumulative cooling effect is relatively greater as the initial temperature (or temperature of the compressed air before release) is reduced. Taking the average cooling effect obtained per atmosphere of pressure released by the nozzle, or .485° F., then if we have 90 pounds constant gauge pressure in the

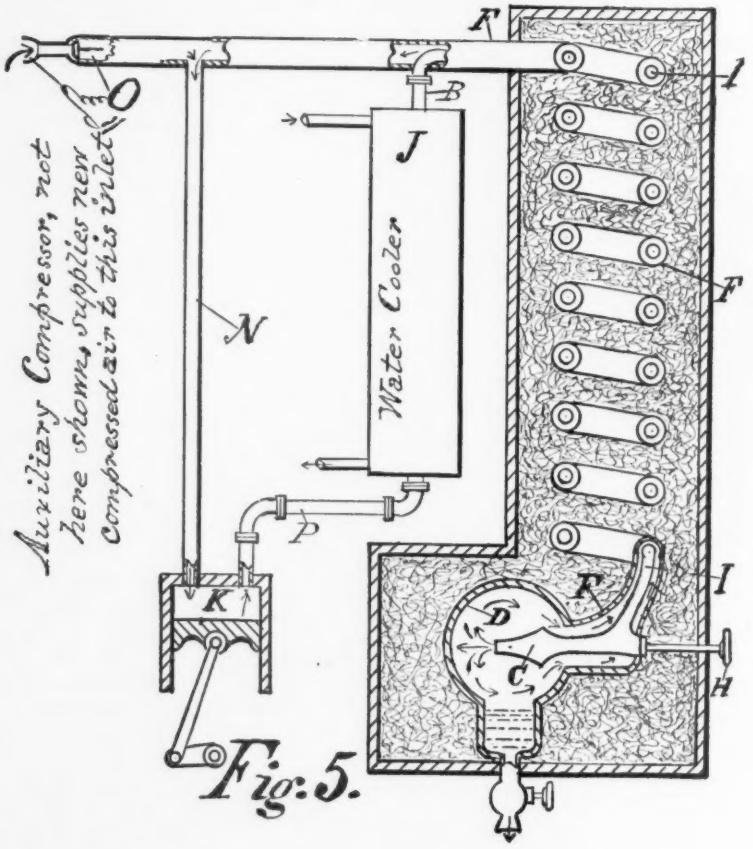


Fig. 5.

pipe I (Fig. 5) at normal atmospheric temperature, the fall in temperature of the expanded air as it escapes from the nozzle and expands to atmospheric pressure will not exceed in the aggregate 2.9 Fahrenheit degrees. This seems a very trifling fall of temperature, and yet in the apparatus for making liquid air as in Fig. 5, it is very doubtful if even that fall of tem-

perature is realized in practice, for the figures given are based on experiments made with the arrangement as shown in Figs. 2 and 3, and not as constructed in either Figs. 4 or 5. In Fig. 4, and especially in Fig. 5, it is a different proposition, as I have previously stated; for the expanded air as it leaves the nozzle is "corralled" or trapped as it were in chamber D and turned back as shown by the arrows. The friction caused by the expanded air thus striking against the walls inside the chamber D and changing its direction has a tendency no doubt to neutralize more or less of the Joule-Thompson cooling effect; and the higher the pressure used, the greater will be the impact against the walls (in D), and consequently correspondingly greater will be the friction (work or motion converted into heat) which is death to refrigeration.

"It is by no means clear to me that the specific heat of the air in both pipes of a Siemens' interchanger is the same. The conditions are very different, for in pipe I of Fig. 5 the air is under a high tension, practically at constant volume, and the work done seems to be localized to the nozzle C (to the friction right in the nozzle), where it is converted into heat, and this heat is immediately absorbed by the work of the expanding air as it passes through the nozzle; while in the outer pipe F the air is at atmospheric pressure, and is continually doing work and expanding at constant pressure as it takes up the heat from the compressed air in pipe I.

"Whatever importance may be attached to the Joule-Thompson effect, it is very clear that liquefaction is produced by the low temperature, and that that low temperature is due to loss of heat by the air; and as that heat cannot have been transferred by conduction to the environments of the air (as such environments were of a higher temperature), it must have been converted into work somewhere—heat and work being equivalents, and temperature simply the evidence of or by-product due to the transformation; and, therefore, that the liquid air is a by-product of the transformation of heat into work. If the specific heat of the air in each of the two pipes of the interchanger is not the same, then the seeming mystery is easily explained; the ratio of the heat consumed by being converted into work in the outer pipe F to the heat given up by the compressed air in the inner pipe I for equal units of weight of air would doubtless approach the well-known ratio of 1.41 to 1 (or .237 to .168, the specific heat of air at constant pressure to its specific heat at constant volume) which would cause a constant lowering of the temperatures sufficient to produce partial liquefaction in spite of the frictional heat generated in D —which is exactly what happens.

"It is quite clear, also, that the Siemens' interchanger is the prime factor in the transformation, and that the nozzle is a detriment instead of a help, and that the cooling effect is produced in spite of the nozzle rather than otherwise. Air was never liquefied in quantity until apparatus using this method through the Siemens' counter-current interchanger was adopted.

"The very high pressures used by the throttled-nozzle system (shown in Fig. 5), in order to liquefy air (generally from 2,000 pounds to 3,000 pounds), makes the process an expensive one, and especially so as only about 5 per cent. of the air compressed can be liquefied. The General Liquid Air & Refrigerating Co., of New York (using the Ostergren apparatus), used but 1,250 pounds pressure, owing to the fact of probably more perfect insulation of the counter-current coils; and they carried the production of liquid air, two years ago, nearer to a commercial basis (in so far as quantity of output means commercial) than any parties that have ever liquefied air either before or since, for they produced at one time from 400 to 450 gallons in 10 hours' run of the apparatus.

"Linde states in his English Patent (No. 12,528—1895), with a view, probably, of showing that the cost of making liquid air by this throttled-nozzle method is more apparent than real, that a pressure of 3,000 pounds per square inch can be used in the inner coil (I, Fig. 5), and that, if such pressure is dropped to 1,500 pounds through the nozzle in the expansion chamber D, then the return flow for cooling (or the expanded air in the outer coil F) will be delivered to the air compressor through the pipe N at that pressure (1,500 pounds); and, if so, 'then a reduction of about 45° Fahrenheit will be obtained with an expenditure of energy that will not be greater than that required for

compressing air from one atmosphere to two atmospheres.' This reasoning might be good provided all the liquid air were evaporated again as fast as produced and carried back to the compressor by the outer coil F, although the reduction in temperature which it is stated would be realized (45 degrees) it is very doubtful; but as for every gallon of liquid air made and drawn from the chamber D, its equivalent or about 800 gallons of new free air must be compressed by the auxiliary compressor up to 200 atmospheres (or 3,000 pounds) and delivered to the apparatus through the pipe O, then the expenditure of energy is clearly not 'from one atmosphere of pressure to two,' but from one atmosphere to two hundred, or from atmospheric pressure to a pressure of 3,000 pounds per square inch. Besides all this power required, there is the power needed to compress the other nineteen-twentieths of the air used in the outflowing or cooling coil F (or 15,200 gallons, in order to make one gallon of the liquid) from a pressure of one atmosphere to two, or 1,500 pounds to 3,000 pounds per square inch. It is also significant that Prof. Linde says in this connection that 'experience has shown that for the mere making good the losses in working, the difference in pressure before and after release (or the drop in pressure in the nozzle), must be greater than 20 atmospheres, (300 pounds).

"Possibly I have taken more space than called for to give these details of liquid-air making; but it has been justly charged that liquid air is costly, and for that reason that it has not met public expectations, and I wish to show, 1st, why it is costly; 2d, that it can be produced at a fraction of its cost hitherto; and 3d, that cheap liquid air means cheap compressed air (which it is, in fact, and in the most concentrated form of compression), and naturally cheap power; moreover, its cheap production leads up to the main object in view—Continuous Power. Other liquid gases, of higher temperature than liquid air, such as carbonic acid, acetylene or ethylene, may be used for continuous power in my system, as the principle of liquefaction applies to all; but liquid air is an ideal substance and represents the best type, the limit as it were, of low temperatures; and the raw material for its production may be had for the taking, everywhere, and is both exhaustless and costless—three good reasons for giving it first a good square test in the system I propose.

"The question here naturally suggests itself to the reader: Why not reduce the cost of liquid air by making the compressed air do work? Why compress air to the enormous tension of 3,000 pounds and then let it escape through a nozzle and thus waste all that energy, when 30 pounds, expanded in an engine, would give a much greater fall of temperature—and the engine be made to do a good part of the work of running the compressor?

"The question is more than pertinent, for the gain in refrigeration or cooling of the air (the by-product) would be very great, and the saving in power required for compressing the air would be enormous, aside from the power utilized from the engine, which would be all 'velvet,' as it were. Let us see how it would look on paper; for instance, referring to Fig. 6:

"Suppose we have an air reservoir A supplied with compressed air at a temperature of 60° F. (the heat of compression having been removed by a cooler), and an expansion engine B, which is belted to a dynamo H. The reservoir A has an outlet valve J and a main pipe E, which is connected by a branch pipe F to the engine through the throttled valve G. The pipe E also has a branch pipe I, which is supplied with a throttled valve C and a nozzle D—the valve C when opened having an orifice of exactly same size as the valve G. (This nozzle D is practically the same as the nozzle D in Fig. 3.) We will say that the valve J is opened at a certain point and locked, and that the pressure in the reservoir A is 91 pounds gauge. By opening the throttle G the engine B will run 200 revolutions, and will develop 10 horse-power in driving the dynamo, and will take all the air that can pass through the valve J; and the pressure in the pipes E and F will show 90 pounds, or one pound less than in the tank A, and the engine will not be run so fast but that the pressure will be maintained constant at that tension (90 pounds)—it being understood that the engine has a cut-off inlet valve, and that it is set so as to cut off at a point of the stroke so that the air will be expanded down (adiabatically) from 90

pounds to exactly atmospheric pressure at every stroke. Now, we will shut off the throttle G and open the throttled-nozzle valve C, and the orifice in valve C being exactly the same as in valve G, the pressure in the pipes E and I is 90 pounds, same as when the engine was running, thus showing that exactly the same number of cubic feet of free air per minute is being delivered from the nozzle D as was delivered from the exhaust K of the engine when it was running—the main valve J not being disturbed, but being fixed and locked at the same point as when the engine was running. Now, what will be the temperature of the expanded air at each respective discharge—D and K?

"The writer has submitted this sketch and this question to more than one mechanical engineer, and has received the startling answer that the temperature would be very cold, but the same in each case; and he has replied, if that is the case, then from whence comes the ten horse power of work?

"If the authorities on the fall of temperature due to the Joule-Thompson effect (which has been fully explained herein) are correct, then the temperature of the air as it expands from 60° F. and 90 pounds gauge after leaving the nozzle D, will be 57.1° F., which is a cooling effect or reduction of 2.9° F. from the temperature (60°) of the air in the pipes E and I. The temperature of the expanded exhaust air at K, from the engine (if the engine cylinder is thoroughly insulated, so that no heat can pass through its walls), will be found to be about 165° F. below zero, which is a fall of temperature of 225° F., or nearly 100 times as much as the theoretical fall at the nozzle D, and probably 200 times as much as the actual reduction in temperature realized in practice.

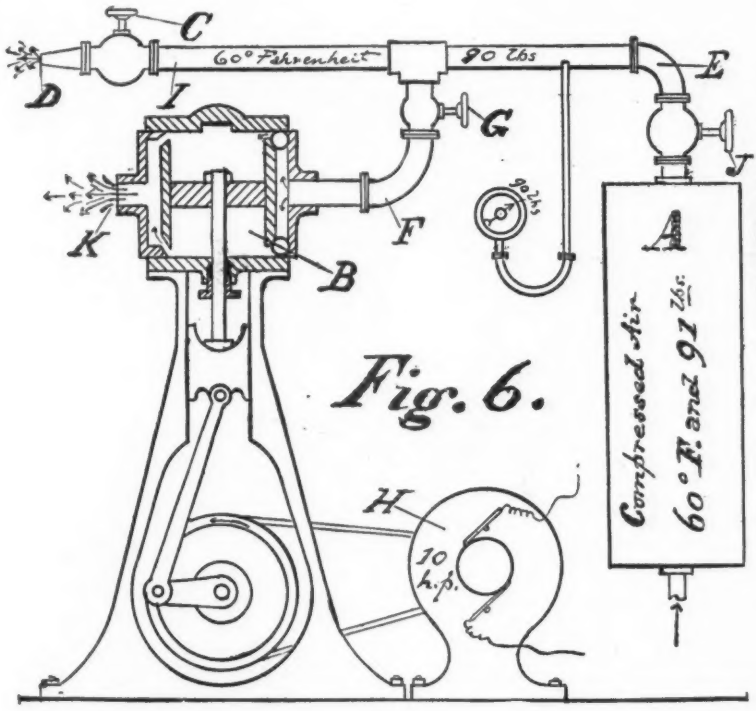


Fig. 6.

"The nozzle D in Fig. 6 is practically the same as used in making liquid air, with the addition of the hood or expansion chamber D, shown in Fig. 5. Now, if we take the engine B (Fig. 6) and muzzle the exhaust K, by adding to it the chamber D of Fig. 5, and the counter-current or Siemens' interchanger coils I and F, (Fig. 5), we ought to get all the advantages of the throttled-nozzle method (by which liquid air has been produced in quantity) besides the advantage of the total gain of the work of the engine, which should be 60 to 80 per cent. of the power required to compress the air used, and the further immense gain of probably 200 times the reduction in temperature of the expanded air, and no frictional heat in chamber D.

"The illustration (Fig. 8) will show the arrangement proposed, wherein is shown the expansion engine having the Siemens' interchanger (same as shown in Fig. 5), and thoroughly insulated from the heat of the outside atmosphere by a vacuum jacket (V) and inclosed in hair felt (H) with also an insulating expansion chamber inclosing the engine and its exhaust ports, and connected with the counter-current or

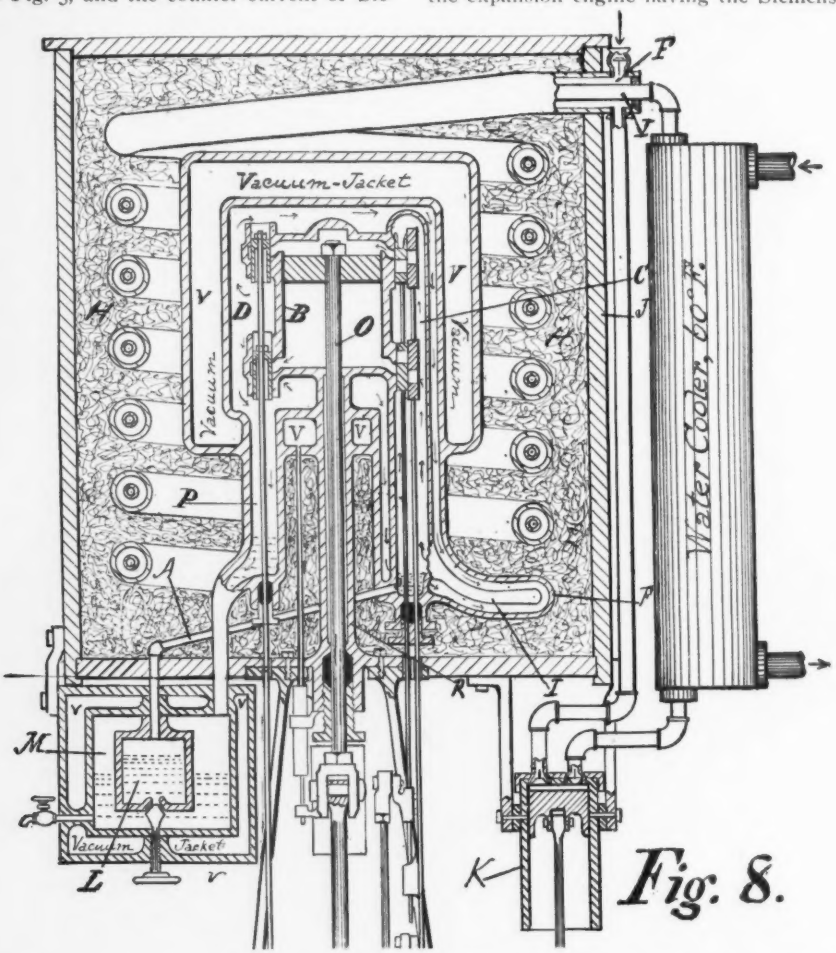


Fig. 8.

return flow cold-air pipe F (same as the pipe F, in Fig. 5) for cooling the compressed air before delivery to the engine.

"In Fig. 8 the expansion engine is shown at B, having a cut-off inlet valve gear and ordinary exhaust valves; at I and F is shown the interchanger, the high-pressure pipe of which (I) is connected with the discharge of the compressor K at one end and with the inlet valve chamber C of the engine at the other end—a branch pipe A connecting with the liquid air receptacle L, which receptacle is to catch the liquefied air which drips down from the inner pipe I of the interchanger, and which is jacketed by an outer receptacle M to catch the liquid discharged from the insulating exhaust chamber D of the engine—the latter liquid being colder than the former, owing to its less pressure. At V is shown an insulating vacuum-jacket inclosing the engine, and at *v* a similar jacket inclosing the liquid receptacles. The compressor is provided with a water-cooler, as shown, and is driven by an outside source of power from the wheel N, the engine, of course, doing a good part of the work, the moisture being absorbed from the air by passing same through a calcium chloride drum (not shown).

"Now, if the air is compressed to 125 pounds gauge pressure, and it is expanded in the engine to atmospheric pressure from a temperature of 60° F., the temperature of the exhaust will be 190° F. below zero, so that, instead of expanded air at a temperature of 57° F. above zero to flow back in the outer pipe F of the interchanger (as in the nozzle operation) the return flow or cooling current of expanded air in the pipe F will be at a temperature of 190° below zero, or a fall of 250 degrees instead of less than 3 degrees, and the expenditure of power for compressing the air is for 125 pounds only instead of 3,000 pounds. As that cold-expanded air passes through the exhaust chamber D and the outer pipe F of the interchanger, the next following charges of compressed air delivered to the engine from pipe I will naturally be at or near that temperature also; and if expanded against resistance from that temperature (190° below) will fall theoretically to 320° F. below zero—thus with but two strokes of the piston, or one revolution of the engine crank, we get a fall of 380 degrees and have reached a temperature actually below the point of liquefaction. It must also be noted that the compressed air in the inner pipe I, near the engine cylinder, being under a pressure of 125 pounds, will liquefy at or below its condensation point, which is 270° below zero; whereas the temperature of the expanded air in the chamber D after the machine is running will be the same as the temperature of liquefaction, or that of saturated vapor at atmospheric pressure, 312° below zero, or 42 degrees colder.

"A less compression may be used, and still satisfactory results be obtained. For instance, with 90 pounds gauge pressure and an initial temperature of 60° F., the temperature of the exhaust expanded air will be 165° below zero; with 60 pounds gauge pressure, the exhaust temperature will be 133° F. below zero; and with 30 pounds gauge pressure the exhaust (from an initial temperature of 60° above) will be 103° below zero—giving a fall in temperature even at that very light compression, of 163 degrees.

"The fall of temperature, or increased refrigeration over and above that of nozzle expansion, if the air is expanded against resistance in an engine, will be exactly equivalent to the work done by the engine; thus, besides having at the engine exhaust all the advantages of the nozzle without its friction, and with probably a much greater cooling effect, we realize in addition a positive gain at both ends—for we gain the power, and the air loses its heat exactly equivalent to that power, is just that much colder, the cold being simply a resultant effect or by-product of the transformation; and cold is what we are after, for by the loss of its heat air becomes liquefied.

"Having produced liquid air with our expansion engine and the interchanger, as shown in Fig. 8 (and trapped it in insulation where the heat of the atmosphere cannot get at it), let us see what results would be obtained if we should use this liquid air over and over again in the same engine—exposing it to and absorbing heat from the atmosphere to evaporate it under a pressure, and then converting that heat into work by expanding against resistance in the engine, thus re-liquefying the air; and then completing the cycle of Carnot's function by returning it to the same con-

dition as to pressure, volume and temperature that it was found in.

"The declaration by Carnot is here worth repeating: 'Wherever there exists a difference of temperature, motive power can be produced.' We have the difference, and it is ample—382° F. But suppose we boil the liquid air, by exposing it to the atmosphere, until 125 pounds gauge pressure is indicated, and use its vapor (air) as fast as it boils at that pressure. Olszewski (and he is good authority) gives as the boiling point of liquid air, under a tension of 125 pounds gauge pressure, as about 270° F. below zero. With the initial temperature at that point, 270° F. minus, the temperature of the exhaust from the engine will be theoretically at 362° F. below zero, which is 50° below the temperature of liquefaction at atmospheric pressure; and the difference of temperature between 270° below and the normal of the atmosphere (70° above) is 340 degrees.

"The critical temperature of air is 220° F. below zero, above which it will not liquefy; and the critical pressure (or pressure required for liquefaction at that temperature) is 39 atmospheres, or 559 pounds gauge, at which critical point latent heat becomes nil. By compounding the expansion engine and working from that or higher initial pressures, or from an initial temperature of slightly above the critical (220° below) the final temperature of the exhaust would be theoretically 370° F. below zero, or 58 degrees below the temperature of liquefaction.

"In the improved form of expansion engine for continuous power, being built by me," says Mr. Place, "provision is made for compound-expansion cylinders, the high-pressure cylinder being supplied from a boiler, and the low-pressure cylinder alone being supplied by a compressor, the latter cylinder exhausting into a partial vacuum in a separate interchanger attached to the exhaust of the high-pressure cylinder as a surface condenser. In this way the temperature of liquefaction of the exhaust of the high-pressure cylinder is raised to about 100 degrees above the temperature of that of the low-pressure exhaust, and the latent heat almost entirely eliminated; this method largely increases the effective power of the engine, and insures absolute and total liquefaction of every exhaust charge, the exhaust chamber being practically also a condenser.

"In Fig. 9 this form of engine is shown in a conventional way, the cylinders being inclosed in the insulating case J, two liquid-air boilers, W, being shown, provided with air flues, S, for supplying same with large quantities of free atmospheric air at normal temperature, from which the moisture has been absorbed by calcium chloride.

"The boilers are supplied with large quantities of free dry air at normal temperature, which is forced through a calcium chloride drum and the flues S by a fan-blower. This air passes up through the tubes in the boilers same as hot air through an automobile steam boiler, and then is carried off through the large insulated cold air flues X, and may be used for cooling or ventilating purposes—the refrigeration thereof being a by-product. The dry free air as it passes through the liquid gas boilers gives up its heat to the liquid (air or other gas) and causes it to rapidly boil (evaporate), and when sufficient pressure is generated a relief valve is forced open and this evaporated liquid gas under tension (cold compressed air or other gas) is delivered to the engine again, and thus the heat which has been absorbed from the atmosphere through the liquid gas boilers is also converted into mechanical work, and the cold expanded gas, thereby losing its heat again, becomes liquefied and is delivered to the insulated receptacle (L, Fig. 9). Practically all of the evaporated gas (with the aid of the condenser), will be liquefied this time, for it is a law of physics that the vapor, gas or steam from a liquid is always of the same temperature as that of the liquid from which it evaporates; therefore the vapor from the boilers (W), under such pressure as desired, will be delivered to and expanded in the engine at the same low temperature as the boiling liquid gas in the boilers. Meanwhile the compressor having stopped working (being arranged as is the common practice to automatically stop when a certain pressure is attained), the power of the engine, derived entirely now from the heat taken from the atmosphere, may be utilized for other work, its speed being limited the same as with a steam engine by the heating capacity of the boiler.

Mr. Place declares that "temperature is not power; it is simply a resultant manifestation—the evidence of the change from heat to power or power to heat. That in the transformation of heat to work in an expansion engine, the fall of the temperature of the expanding air is a by-product of the operation; and that refrigeration being a by-product, necessarily liquid air is also a by-product of the conversion of heat into work in an insulated expansion engine. That heat and power alone are the equivalents, one of the other—not temperature. Nature deals in equivalents, it is true, and its laws are most exacting; but there can only be two equivalents—one of the other; there cannot be a third. The temperature, the refrigeration, or liquid

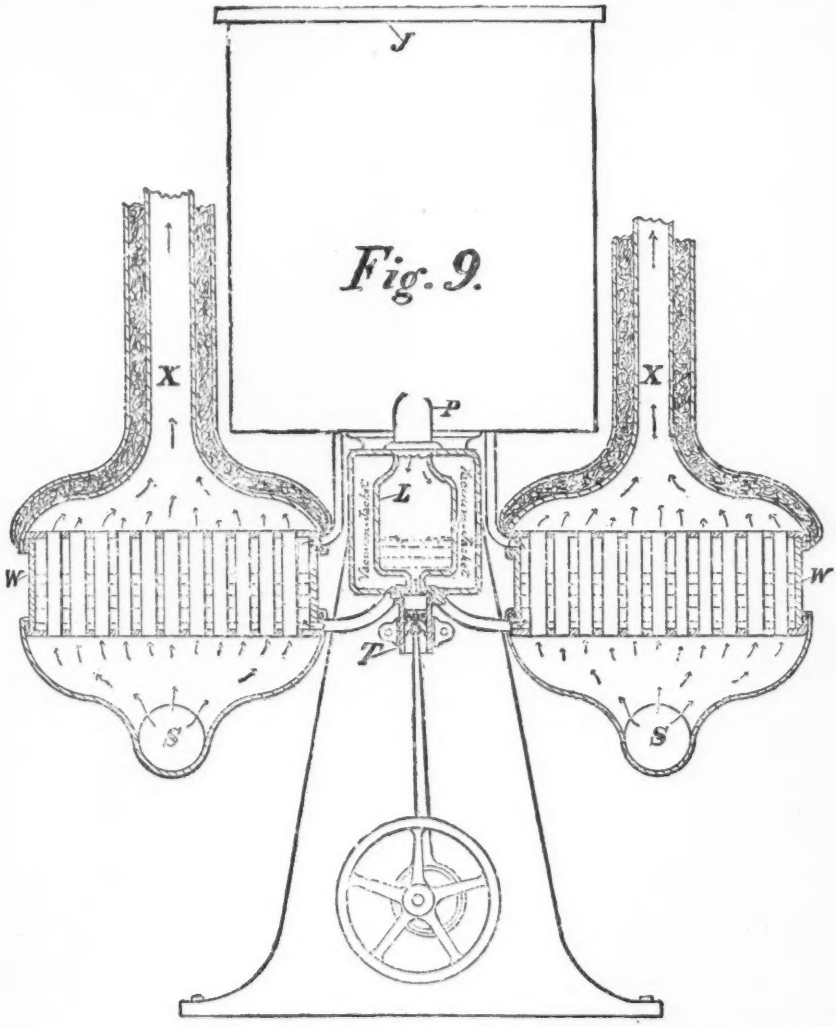


Fig. 9.

air, if you please, has cost no energy; the work recovered is the mechanical equivalent of and has cost (if such a term may be used) all the energy (heat) expended; therefore the temperature, refrigeration or liquid air is simply the evidence of the loss or disappearance of the heat transformed, and is consequently a by-product of the operation of the conversion of such heat into work.

"I have disproved by actual experiments at least three theories which had become through popular fallacy 'bogies' of the first magnitude, namely—1st, that an engine cannot be run without lubrication; 2d, that thorough insulation cannot be maintained, and 3d, that the moisture in air cannot be removed.

"Experience shows that an engine can be run without lubrication, and that it runs better cold than hot; that thorough insulation of an engine cylinder is as easy of attainment as the insulation of a steam pipe from the normal temperature of its surroundings; and that by the passage of compressed air through a drum filled with calcium chloride the moisture thereof may be thoroughly absorbed therefrom."

The Substructure for the 1,800 Ft. Cantilever Bridge at Quebec, Canada.

The longest span bridge in the world is now in process of construction across the St. Lawrence River, about seven miles west of Quebec, Canada.

The substructure of the Quebec Bridge consists of three masonry structures on each side of the river as follows: An abutment on the top of the rocky cliff, an anchor pier at the foot of the cliff and 210 ft. from the abutment, and a main pier near the margin of low tide and 500 ft. from the anchor pier. The two main piers, as before stated, are 1,800 ft. apart. Those on the north shore were exactly similar in all respects, except the volume of masonry contained. The same statement is true with respect to the main piers. The masonry is granite face work with concrete backing, except the coping courses of the abutments and anchor piers and the upper 19 ft. of the main piers, which are solid granite masonry throughout.

The most interesting features of the foundation work are the construction, equipment and method of sinking the caissons and the contractor's plant and equipment for performing the construction work of the main piers. Since all these features were the same, except in minor details, for both piers, a description of the south pier work alone is sufficient to explain clearly all the work.

The caissons for the two main piers were identical in construction and dimensions, and were 49 x 150 ft. in plan and 25 ft. high. The timber used was yellow pine from Georgia, and all main timbers were 12 x 12 ins. in section after dressing. The outside sheathing consisted of two layers of crossed diagonal planking spiked to the sidewalls. A single layer of planking was employed to sheath the ceiling and walls of the working chamber and both sides of the dividing bulkheads. This chamber was 6¼ ft. high in the clear and was divided into six compartments by the transverse bulkheads 2½ ft. thick, just mentioned. The sidewalls at the bottom are beveled at a very flat angle to make a cutting edge 9 ins. wide, which is shod with a ¾-in. x 6-in. x 6-in. steel angle. Generally speaking, the construction of the caissons involves no new features other than the method employed to avoid annoying leaks of water into the shafts due to the wide variation of tide level, and their construction requires no further description than is given in the plans.

The trouble from leakage and the method of remedying it may be described as follows, premising first that the six compartments of the air chamber were each made accessible by means of a material shaft 3 ft. in diameter. It was found that the rising tide would fill the shaft wells with water and that, aided by the leaks of air from the chamber, this water would reach a height somewhat above the river level. No trouble was experienced from the leakage of this water into the shafts until the tide began to fall and the air pressure was correspondingly reduced, when the water in the shaft well escaping less rapidly than it had come in would soon exceed the chamber air pressure, and thus force an entrance into the shafts at the deck line and into the chamber at the ceiling by loosening the oakum in the seams. But for the fact that the

air chamber was double-calked with four threads of oakum, this excessive inward pressure would have caused very serious trouble by entirely dislodging the oakum. As an indication of the pressure encountered it may be noted that on one occasion during extreme high tide alarm was given that the roof of the caisson was caving in, when, upon investigation, it was found that this excess water pressure was great enough to draw the ½-in. x 7-in. spikes with which the 3-in. lining was spiked to the roof timbers near a shaft, and force several planks downward, giving the appearance of the roof giving

vided with a material shaft, a blow-out pipe, an air signal pipe and a water pipe. The main air supply pipe entered through the roof of one of the center compartments. The longitudinal sectional elevation, Fig. 2, shows the arrangement of the water and blow-out pipes.

The six working shafts were built of 8-ft. sections of 36-in. wrought-iron cylinder bolted together with gaskets and outside flanges, and connected to the deck with 24 ¾-in. bolts passing through a special cast deck flange, and the three courses of deck timbers, as shown by Fig. 1. There were two plain shafts used

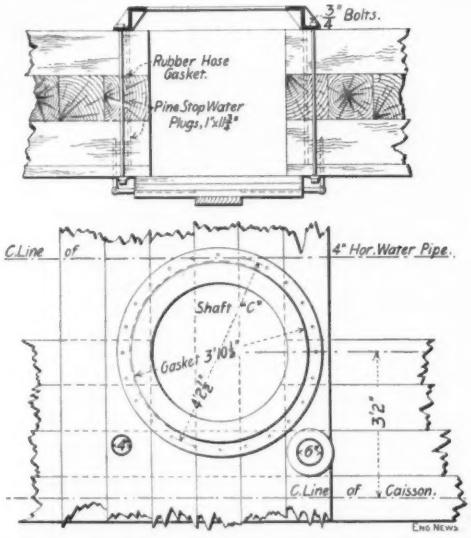


FIG. 1—DETAILS OF AIR-SHAFT OPENING IN DECK OF MAIN PIER CAISSONS.

away. The leakage mentioned was greatest and most annoying where the shafts passed through the deck, and profiting by the first experience, rubber gaskets in the horizontal seams and stopwaters in the vertical seams were employed around each shaft opening, as shown by Fig. 1. These devices proved to be an effective remedy for the trouble.

The equipment of the caisson for sinking comprised air and water pipes, material shafts, air locks and accessories. Described in more detail, each compartment of the working chamber was pro-

for materials only and four ladder shafts used for both material and workmen. The cross-section of the ladder shafts in each case consisted of 300° of a circular cylinder, and for the remainder of the perimeter of a bent plate offset beyond the circle. The space afforded by this off-set accommodated a ladder, and thus left a 36-in. diameter space clear for the passage of material, as shown by Fig. 3. The two plain shafts were complete cylinders 36 ins. in diameter, and were the only ones provided with material locks.

The two material locks were adapted to

work on top of any of the six shafts, but during the process of sinking the caisson were kept on the two plain shafts, and material which would not pass the blow pipes was accumulated at the foot of these shafts by passing it from the adjacent chambers. When sealing the chamber, the locks were transferred from shaft to shaft as each compartment was filled with concrete. A portable platform was built level with the top of each lock and skips filled with concrete were landed thereon and dumped directly into the locks, and when the latter were equalized the charge of concrete would drop through the shaft into the air chamber, where it was shoveled into place and rammed.

The ladder shafts were all converted into man locks by inserting between the sections of the shaft a diaphragm containing a door. Each ladder shaft was

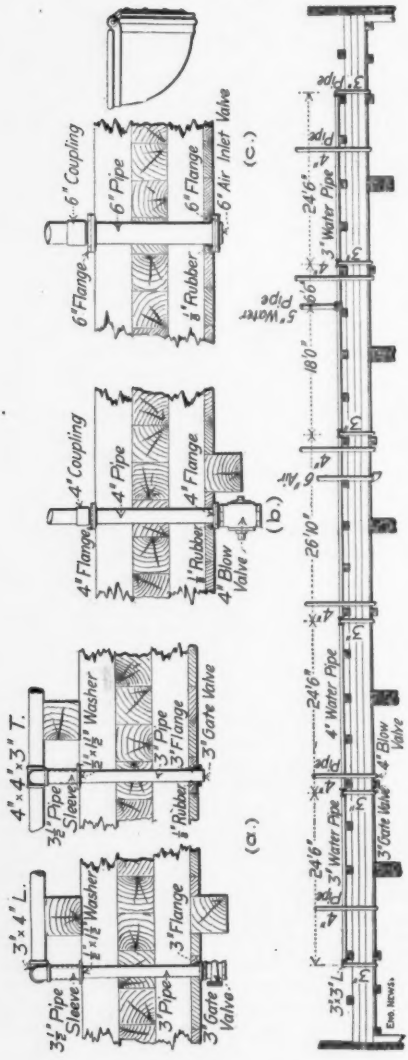


FIG. 2—GENERAL DETAILS OF PIPE OPENINGS IN DECK OF MAIN PIER CAISSONS.

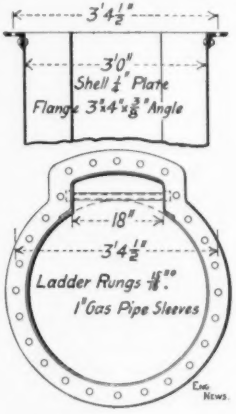


FIG. 3—DETAILS OF MATERIAL SHAFTS FOR MAIN PIER CAISSONS.

provided with two of these and they were raised as new sections of shaft were added. Before using any of these shafts for concreting, the top diaphragm and door was removed and a Moran lock put its place. The lower of the two diaphragms was made up of two plates, the smaller one containing the door being slightly smaller than the shaft was unbolted from the larger plate and lowered into the air chamber, thus leaving a circular opening 2 ft. 7½ ins. in diameter through which the concrete could readily drop when released from the lock. By the use of these diaphragms it will be seen that man locks of varying capacity could easily and quickly be made. After sealing the chamber, all the shafts were unbolted from the

cast-iron Z-bar shoe and lifted out in one piece and the several sections afterwards unbolted, thus preserving the shafts unhurt.

The material locks used were Moran locks and were attached to the tops of the two plain shafts. The construction of one of these locks is shown in detail by Fig. 4. As will be seen, the lock chamber is about 12 ft. long and 5½ ft. in diameter, and is provided with upper and lower doors. The lower door is circular and double-hinged so that it swings entirely clear of the opening. The upper door is made of two halves hinged to links, which work in guides carrying them away from the opening. Both doors close on rubber gaskets and are operated by counterbalanced shafts. To permit the working of the hoisting rope through the upper door when closed a semicircular groove is cut in the closing edge of each half which form a circular hole when the door is closed. A stuffing box carried by the rope closes this hole against the escape of air while allowing the rope to pass freely through it. Fig 4 shows the construction of this stuffing box, and of all other details of the air locks.

The two locks described were used continuously in sinking the caissons, and proved to be very valuable machines. They were capable of passing iron buckets 34 ins. in diameter and 48 ins. deep, these buckets being filled with excavated material and hoisted directly from the air chamber by a ⅝-in. wire rope operated by a hoisting engine located on the working platform. With the aid of these two locks in passing the concrete to the working chambers, perhaps the quickest work in sealing an air chamber of such size was done in sealing the chamber of the north caisson. The work was begun at 7 a. m., Oct. 31, and contiuously prosecuted until 7 a. m., Nov. 6, when the work was completed. During the 144 hours of actual work about 1,500 cu. yds. of concrete were passed into the air chamber, the largest record being 250 cu. yds. in twelve hours of the night of Nov. 3.

Referring to Fig.2, it will be seen that a 4-in. water pipe is run along the deck of the caisson near the longitudinal center line, which has six vertical 3-in. pipes extending into the six compartments of the working chamber. There are also six blow-out pipes 4 ins. in diameter, one extending into each compartment. The water pipes having gate valves and the blow-out pipes have special cast-iron plug valves, giving a 4-in. clear way for the passage of mud, sand and small stones. The connections of the water and blow-off pipes to the caisson deck are shown at (a) and (b) in Fig. 2. The air pipe is 6 ins. in diameter. It passes through the caisson deck and terminates in an elbow, the horizontal open end of which is closed by a hinged iron disk faced with leather. The details of this pipe are shown at (c) in Fig. 2.

The caissons were constructed on the north bank of the river, at a point about 4,000 ft. below the site of the bridge. They were built ready to sink before launching, and weighed about 1,600 tons each. The launching ways were four in number, each 30 ins. wide and about 300 ft. long, and having an inclination of 1 in. per foot. The running ways were 32 ins. wide and 60 ft. long, and had an effective bearing area of about 550 sq. ft. in the aggregate, thus making a load of about three tons per square foot at the time of launching. Owing to this great pressure some difficulty in launching was apprehended, but by the use of a superior beef tallow thoroughly and freshly applied, the friction was so reduced that the effort down the ways was great enough to split four 12 x 12-in. yellow pine sticks with the grain through a length of 12 ins., and release four 1½-in. screw bolts with which the two end sliding ways were bolted to the fixed ways. The launch was made broadside on, and without accident in case of either caisson.

The north caisson was launched on June 20, 1901, and the south caisson on May 26th, 1902. Prior to launching each caisson a timber working platform having an area of about 12,000 sq. ft., was built on piles around the corresponding pier site. The piles for these platforms were shod, the better to penetrate the boulder formation.

At the site of the piers the water had a depth of about 10 ft. at low tide and 29 ft. at high tide. As the caissons unloaded drew about 12 ft. of water they grounded at low tide and floated at high tide. The widely varying tidal range occasioned no trouble or inconvenience in handling the

caisson while afloat, but when it would barely float at high tide care was required to have it grounded in correct position. Before the next high tide, 12 hours later, sufficient concrete would be added to prevent the caisson from floating again. Therefore as soon as the caissons were in position the work of loading them with concrete was begun and prosecuted continuously until the crib-work above the deck was entirely filled ready to start the pier masonry.

cutting edges of the caissons as much as 4 ft. without any difficulty, thus greatly facilitating the removal of boulders.

All boulders too large to enter the 34 x 48-in. iron buckets used in removing the excavated material were drilled and broken by dynamite, 3,000 lbs. of this explosive being used in sinking the south caisson, and without a single case of injury from this cause and without the men suffering from the gases evolved. The air chamber was lighted by 16-c. p. in-

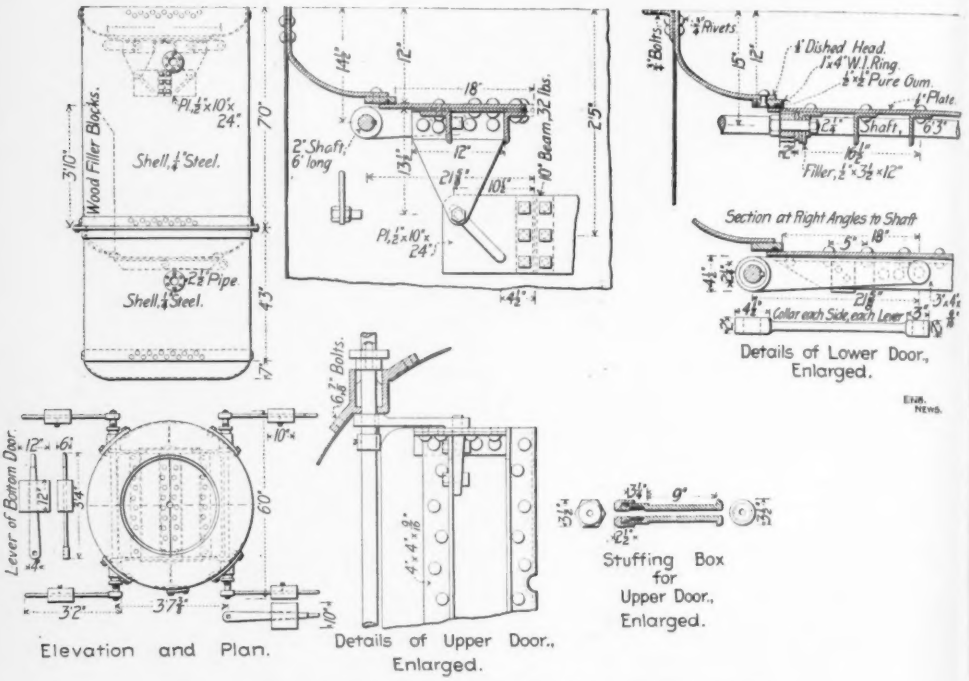


FIG. 4—DETAILS OF MORAN AIR LOCK FOR MAIN PIER CAISSONS.

Simultaneously groups of men were put at work in the chamber excavating and removing the boulders constituting the river bed. There were no unusual features in sinking the caissons other than the material to be penetrated, which consisted of sand, gravel and boulders, some of which were many tons in weight, so compacted as to be impervious to compressed air. Due to this latter fact it was possible to keep the excavation below the

candescent electric lamps, about 100 being used in the six chambers. The current which supplied the lamps was also used to fire the dynamite charges by attaching the leading wires to a lamp socket. When a blast was to be fired the most convenient lamp was unscrewed and the socket attached to the leading wires was inserted and as soon as contact was made the shot was fired. This proved to be quicker, more reliable and more economical than

the blasting battery generally used for such purpose.

The sinking of the south caisson was begun on June 7, 1902, and finished on Oct. 17, thus requiring 131 days to sink 59 ft., or at an average sinking of 5.4 ins. per day, varying from a minimum of 2 ins. to a maximum of 10 ins. The number of men employed at the bridge site varied from 500 to 600, and at the quarry at Riviere a Pierre from 100 to 300. The number employed in the air chamber of the south caisson varied from 225 to 300, divided in the beginning into three shifts of eight hours each. This continued until a depth of 50 ft. was reached, when four gangs were employed, working six hours each. When a depth of 65 ft. was reached, six gangs were used, working four hours each, until a depth of 75 ft. was reached, when eight gangs were employed, working three hours each until the final depth of 80 ft. was reached. The maximum air pressure used in sinking the south caisson was 36 lbs., and was endured by the men with little inconvenience and without developing any serious case of "bends."

It is impossible to determine with any exactness the percentage of materials removed through the blow pipes, as no means were used to gauge the volume, but it is believed that this percentage did not exceed 10 per cent. in the case of the north caisson or 25 per cent. in the case of the south caisson. The north caisson was sunk to a depth of 60 ft. below high water, but owing to the existence of a widely extended pocket of sand at this depth on the south shore, the south caisson passes through this sand and to a depth of about 80 ft. below high tide, giving it a penetration of 59 ft. into the boulder formation.

The compressed air power plant which supplied all the power for the work, consisted of three duplex compressors, with 16 x 18 x 18-in. cylinders; one 16 x 10 x 10-in. duplex high pressure pump; one 18 x 10 x 12-in. duplex high pressure

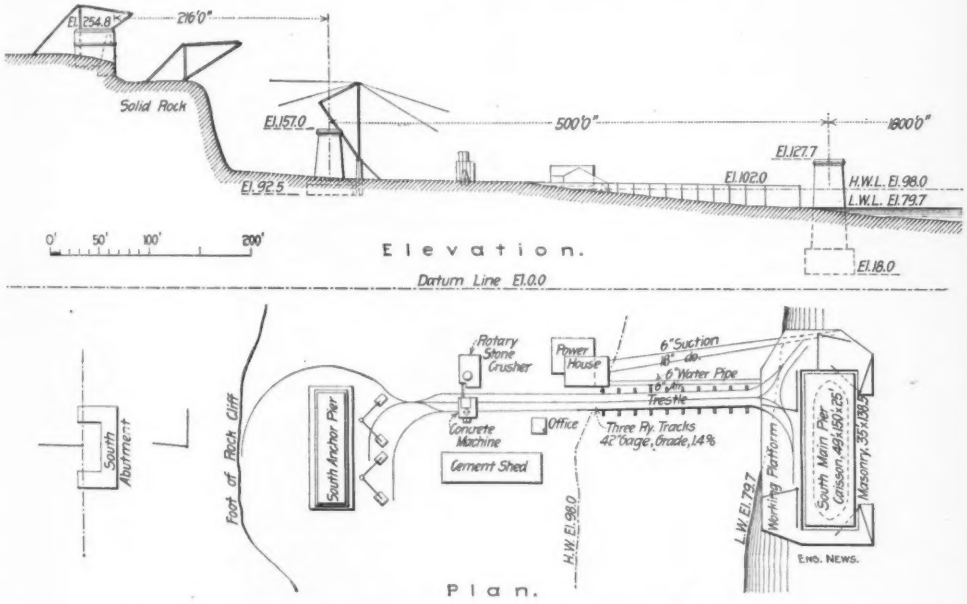


FIG. 5—PLAN AND ELEVATION OF CONTRACTOR'S PLANT FOR SOUTH SHORE ABUTMENT AND PIERS.

pump; one 18 x 10 x 10-in. duplex high pressure compound pump; one 10 x 18 x 18-in. single jet condenser; one 10 x 6 x 10-in. duplex boiler feed pump; two 6 x 4 x 6-in. duplex boiler feed pumps; two 7½-KW. electric light generators, and two Moran air locks. This machinery and all the hoisting engines were supplied with steam by a battery of six 100-HP. boilers working under forced draft and supplied with hot water through a feed water heater. The power house and machinery, including the boilers, was set on a heavy concrete foundation. The water supply was taken from the river through one 18-in. suction pipe, a 6-in. pipe also being laid for use in feeding the boilers in event of accident to the 18-in. pipe.

The contractor for the substructure of the Quebec Bridge was Mr. M. P. Davis, of Ottawa, Ontario, whose staff consisted of Mr. A. A. Stuart, M. Am. Soc. C. E., Resident Manager; Mr. W. L. Scott, Mechanical Engineer; Mr. Henry Barnes, Day Superintendent, and Mr. Charles George, Night Superintendent of Pneumatic Work. Mr. Stuart states that the substructure work will involve a cost in treasure of about $1,200,000.—*Engineering News.*

Pneumatic Jack.

Our attention has been called to a new form of Pneumatic Jack, which is the invention of Mr. Jas. Macbeth, Supt. of the car shops of the New York Central R. R., at Buffalo, N. Y. This jack consists of a large and small cylinder placed side by side, both mounted on a single base having two wheels and a suitable handle for moving about. The larger cylinder is about 15½" in diameter and has inside a piston rod with two large pistons properly packed. The lower end of the piston rod is enlarged and works in a small oil or hydraulic pump cylinder. This connects with the outside or jack cylinder. The lower portion of the large cylinder is used as an oil reservoir to supply the pump cylinder.

In operation air is admitted to the upper sides of both of the large pistons, this exciting a double pressure on the piston rod which is forced down into the pump cylinder, and forcing the oil over into the jack cylinder. The pump cylinder being only 4" in diameter the pressure is largely multiplied. Each full stroke of the large combined piston of about 7" forces the jack plunger out the same distance. A check valve is placed at the bottom of the jack cylinder so that the plunger cannot slip back. A two-way valve is provided to admit air to the top of both working pistons or to the bottom of the upper piston to make the return stroke. A by-pass valve also allows the oil to flow back from the jack cylinder to the reservoir. The usual hose coupling and length of flexible hose is also provided for. It is claimed that with 100 lbs. air pressure this jack will lift 37,252 lbs. Referring to the device, Mr. E. P. Mooney says:

"I have seen this jack in operation from time to time and will candidly say it is about the only appliance on the market to-day, that will raise these 100,000 lb. cars without using a double set of hydro jacks.

"I have also seen this jack tested when the car has been raised, and the air hose disconnected, and must say it is an impossibility to have an accident occur by having any part of the jack or hose give way, in other words, if the hose, air pipe or any part of the jack should give out, the air is locked in the jack in such a manner that it is impossible for the load to come down.

"Another important feature of this jack is that the left piston is so offset from the center line of the cylinder of jack that they can be placed under steel cars at the body bolster and not interfere with the moving of the truck under car when it is jacked up, as is the case with all other air and hydro jacks."

Port Huron Air Motors and Drills.

The illustrations show a line of pneumatic apparatus recently designed and manufactured by the Port Huron Air Tool Co., Ltd., of Port Huron, Mich. The firm is a comparatively recent organization and has been formed with the intention of bringing out special designs in air driven mechanism and practically applying them to jib cranes, stationary motors, traveling cranes, etc.

The Port Huron motor consists of a couple of oscillating cylinders, each double acting and set at right angles in an air tight case as shown in the interior view of the motor seen in Fig. 1. There is no movable valve mechanism as the oscillation of the cylinders opens and closes the ports and causes a sharp cut-off. A small quantity of oil is kept in the case so that the crank splashes the lubricant upon the valve seats and the air carries it through the inlet ports to the pistons. All motors are reversible and those of the same size and type are interchangeable. It will be noticed that the cylinders oscillate from the extreme end. There are eight ports to each engine. When the engine is on the dead center the air is shut off. Four of the ports of each cylinder head operate at the same time, two feeding and two exhausting so that when the engine turns off the dead center the feed and exhaust ports open and when the engines are on half stroke the ports are wide open and then gradually close until the dead center is reached and the cycle of operations commences anew.

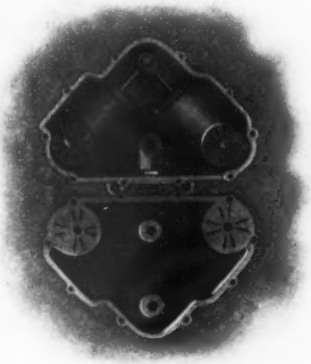


FIG. 1—INTERIOR VIEW OF THE PORT HURON MOTOR.

The cylinder head is a bronze casting and the cover is cast iron on all motors. The cylinder heads in the drills are

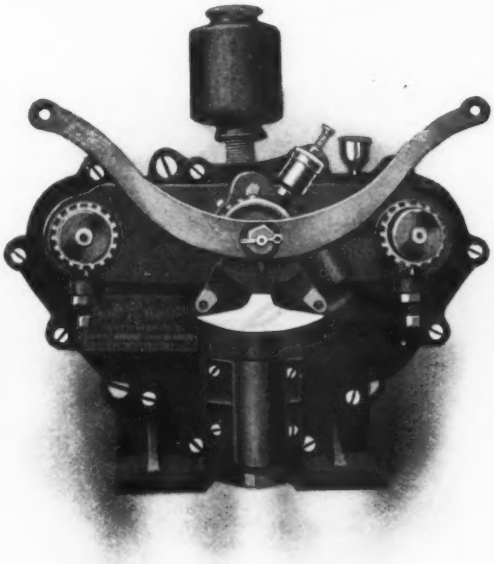


FIG. 2—FRONT VIEW OF STATIONARY AIR HOIST.

bronze castings whilst the covers are made of aluminum with steel bushings. The two wearing surfaces are thus of different metals and are scraped to a surface plate and the engines are all tested under pressure and sent out perfectly tight. The cylinder rocks on a trunnion which is stationary with a spring under the lock nuts on the cover. The spring is made strong enough to take up all wear that may come on the two faces. The bearing fits on the pin for the full width of the box and the oscillation is so small that it takes proportionately about six turns of the crank shaft for one turn on the trunnion. Every bearing is bronze bushed and the shafting is made of high grade steel.

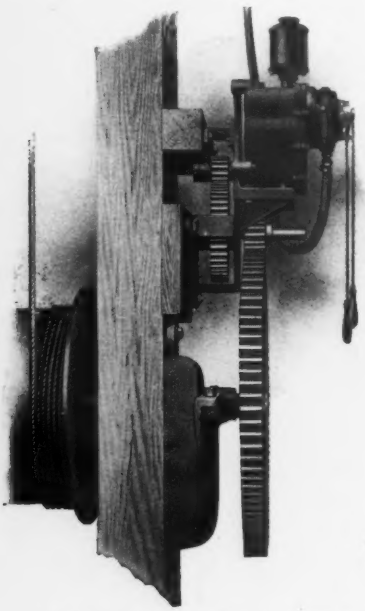


FIG. 3—STATIONARY MOTOR APPLIED TO JIB CRANE.

The drills are made with aluminum cases. The drill is readily reversed by a three-way valve. When the tool is employed in boiler tube work, the reverse movement is of great convenience in contracting the expander for the next operation. The gear box is interchangeable so that the tool can be made to tap holes up to 1½ inches by a variation in the gearing ratio, the spindle speed being from 30 to 40 turns per minute.

The motor illustrated in Figure 3 is gearing for attachment to a jib crane or derrick and may be applied in a similar manner to locomotive turntables or the running of any individual machine. A 4-ton air motor hoist is shown in Figure 4. The motor handles the load through straight line gearing at the rate of 12 feet per minute. The company claims that the hoists will lift as much again as the catalogued capacity and that the hose may be disconnected and the load held indefinitely without the use of any additional brake. The valve is operated by two chains reaching to within four feet of the ground and by this means the motor may be instantly stopped, started or reversed. The valve is self closing when the chains are released. The hoist is made with a winding drum and equipped with a wire rope, with double or triple sheaves and will lift from one to ten tons. Twenty-four of these stationary motor hoists are in use by the Bass Foundry & Machine Co., of Fort Wayne Ind.—*Iron Trade Review.*

Various Methods of Conveying Power to the Interior of Mines.*

One of the most useful methods of transmitting power to a distance, and one of the best adapted to the requirements of mining, consists in the employment of compressed air as the medium of transmission. It is worth while taking note of the fact that this method was introduced as early as 1849 for driving an underground winding engine at Govan Colliery by Messrs. Randolph and Elder—the predecessors of the present Fairfield Shipbuilding and Engineering Company. But the greatest impetus to the employment of compressed air in mining operations was given when the first long railway tunnels through the Alps were being driven. The Mont Cenis and St. Gothard tunnels—respectively seven and nine miles in length, without intermediate shafts—would have

*A paper read before the Glasgow University Engineering Society, by Mr. T. Linsey Galloway, December 4, 1902.

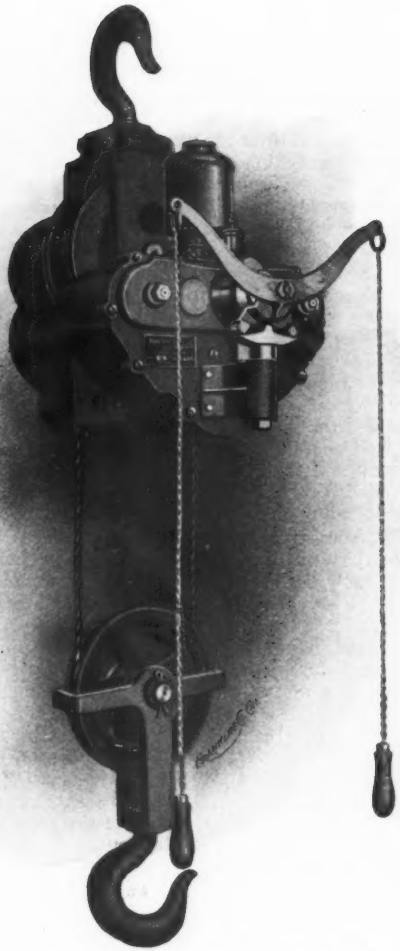


FIG. 4—PORT HURON 4-TON AIR MOTOR HOIST.

been a financial impossibility without the use of mechanical rock drills which enabled the work to be completed within a reasonable time. The drills were driven by means of compressed air, which was conveyed by a line of pipes from compressors near the entrances to the tunnels. The compressors were actuated by water power obtained from the mountain streams. M. Sommeiller, the engineer who had charge of the Mont Cenis Tunnel, demonstrated the practicability of conveying power by compressed air, without serious loss, for a distance of four or five miles; and the experience gained at the Mont Cenis Tunnel and in subsequent undertakings, led to great advances in the construction and design of rock drills and air-compressors. It was a remarkable achievement in those days when electric transmission was still unthought of, that the impetuous Alpine torrents should have been harnessed in the service of man, generating power which could be conveyed far into the interior of the mountains, and making it possible eventually to pierce those rocky barriers from side to side. Compressed air is well adapted to driving all the various classes of machines, which are usually required in the interior of mines. The machines themselves do not essentially differ from ordinary steam engines, except that the exhaust passages should be as short as possible, and of ample area in order to prevent them from becoming choked with ice. In coal mines which are liable to the dangers arising from explosive gas and dust, compressed air is specially prized as a means of driving drills and mining machines. Its absolute safety constitutes one great recommendation. Another advantage, which applies to mines of all classes, is that the low temperature of the exhaust helps to cool the mine and assists the ventilation. One of the difficulties of deep mining arises from the ever-increasing temperature of the earth's crust. The rate at which the natural temperature of the rocks increases has been the subject of much investigation. Many observations have been made in all parts of the world, from which it appears that no uniform rate can be established which will be applicable to all cases. A rock temperature of 80 to 90 degrees, however, is by no means unusual in deep mines, and it will readily be understood that the cooling effects arising from the use of compressed air are much appreciated under such circumstances. In the gold-mines of the Transvaal it is customary, when work is suspended at meal hours, to open up the mains and allow the compressors to run full speed, with a view to cooling and improving the ventilation, a circumstance which the manufacturers of compressors require to take into account in designing machines well governed and of sufficient strength to withstand the extra strain so brought upon them. The chief defect of compressed air as a medium for transmitting power arises from the waste of energy which generally takes place. When air is compressed, a great amount of heat is developed in the process. This heat is rapidly lost as the air passes along the pipes. When it arrives at the motor it has attained practically the same temperature as the atmosphere of the mine. After it has done its work, and is exhausted from the motor, it falls to a low temperature in expanding to the atmospheric pressure. The latter circumstance is a positive advantage from a sanitary point of view, as already stated. But the heating of the air during compression entails a positive loss of power by dissipation of energy, and is therefore to be avoided as much as possible. Formerly several devices were introduced for keeping the air cool. The compressing cylinder was enveloped in a cold water jacket—a jet or spray of cold water was injected into the cylinder—or the cylinder was completely filled with water, as in Sommeiller's compressor, and the air was compressed in vertical chambers at each end of the cylinder in which the water rose and fell with the reciprocating motion of the piston. Most of these devices have now disappeared in favor of the system which is known as stage compression. In this system the air is first of all raised to a certain intermediate pressure. The heat which it has developed is then extracted by causing it to pass through a cooler. It then passes on to a second compressing cylinder in which it undergoes further compression. It may be again cooled and the same process continued to higher stages, but only two stages are generally employed in the case of pressures not exceeding 100 lbs. An instance may be given by some particulars

of a pair of air-compressing engines by Messrs. Walker Brothers, of Wigan. The steam cylinders are on the Corliss principle. The engine frames are of the trunk type. The Corliss valves are controlled by a governor. The air cylinders are on the double stage system of compression, with cylindrical water jackets. The intermediate cooling apparatus consists of a large number of brass tubes enveloped in water, which is made to circulate by means of a pump. The steam cylinders are 33 in. and 57 in. in diameter respectively; the air cylinders are 29 in. and 48 in. in diameter respectively. Length of stroke, 5 ft. The approximate air pressure is 100 lbs. per square inch.

In order to exhibit the advantage of double-stage compression, we shall make a calculation of the amount of energy required to compress air under various suppositions. If air could be compressed without any rise of temperature, its pressure would vary inversely as its volume, in accordance with Boyle's law. This would be the case if the heat due to compression could be abstracted as quickly as it is produced. Under these circumstances it is easy to prove that the number of foot pounds necessary to compress a mass of air from pressure p_a to pressure p_b would be

$$W_1 = p_a v_a \log_e \frac{p_b}{p_a}$$

This is the ideal towards which actual compressors should approximate, but to which none ever attains. On the other hand, if there were no abstraction of heat at all during the process of compression, the ratio of pressure and volume would follow the law of non-transmission of heat, according to which

$$v = v_a \left(\frac{p_a}{p}\right)^{\frac{1}{\gamma}}$$

where γ is the number 1·41 which expresses the ratio of the specific heat of air at constant pressure to its specific heat at constant volume. On this supposition, the energy required would be

$$W_2 = \frac{\gamma}{\gamma - 1} p_a v_a \left\{\left(\frac{p_b}{p_a}\right)^{\frac{\gamma-1}{\gamma}} - 1\right\}$$

In practice, however, neither this nor Boyle's law expresses what actually takes place, because there is always some cooling effect produced during compression by radiation and conduction of heat from the compressing cylinder, even if no special means of cooling are adopted. Under these circumstances the law of variation of pressure and volume may be assumed to lie between the two extremes, and to be of the form

$$v = v_a \left(\frac{p_a}{p}\right)^{\frac{1}{n}}$$

where n is the number greater than unity but less than 1·41. On this supposition, the energy required would be

$$W_3 = \frac{n}{n-1} p_a v_a \left\{\left(\frac{p_b}{p_a}\right)^{\frac{n-1}{n}} - 1\right\}$$

Now, if the air, instead of being compressed in one stage, from p_a to p_b, is first compressed to an intermediate pressure, which we shall denote by p_m, and is then cooled to its original temperature, and afterwards compressed from p_m to p_b in another cylinder, as in the compressing engine just described, the amount of energy expended will be expressed by two terms similar to the last, viz.:—

$$W_4 = \frac{n}{n-1} p_a v_a \left\{\left[\left(\frac{p_m}{p_a}\right)^{\frac{n-1}{n}} - 1\right] + \left[\left(\frac{p_b}{p_m}\right)^{\frac{n-1}{n}} - 1\right]\right\}$$

But in this formula p_m is indeterminate. In order to obtain the best results from two-stage compression, however, it is evident that this expression ought to have its minimum value, and adopting the usual process of the differential calculus, we find that this will be the case when—

$$p_m^2 = p_a p_b.$$

Accordingly, the best result of two-stage compression is obtained when we substitute the value of p_m thus determined, and the final result is—

$$W_5 = \frac{2n}{n-1} p_a v_a \left\{\left(\frac{p_b}{p_a}\right)^{\frac{n-1}{2n}} - 1\right\}$$

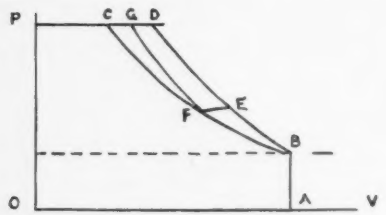
It is easy to deduce also what the relative diameters of the two compressing cylinders ought to be, supposing they have the

same stroke, as is usual; the result is as follows:—

$$\frac{D}{d} = \left(\frac{p_b}{p_a}\right)^{\frac{1}{4}}.$$

For example, if the final pressure is to be 100 lbs. above atmospheric pressure, the diameter of the larger cylinder ought to be one and two-thirds that of the smaller, a result which agrees exactly with the practice of the best makers.

All the foregoing formulæ are illustrated by the accompanying diagram. O V is the direction in which volumes are measured; O P is the direction in which pressures are measured; the dotted line indicates the atmospheric pressure; O A is the initial volume; B F C is the curve of isothermal compression; B E D is the curve of singe-stage compression; B E represents the first stage in two-stage compression; E F is the shrinkage of volume in the passage of the air through the cooler; F G is the second stage of compression. The area D E F G represents the saving effected by double stage as compared with single-stage compression. In order to illustrate these results, let us take a numerical example. We shall assume the index n to have the value 1·25, a value which agrees with actual experiment, and let it be required to compress air from atmospheric pressure to 100 pounds per square inch above atmospheric pressure. Using these data, and remembering that the pressures in the formulæ are absolute, so that $p_a = 14{\cdot}7$ and $p_b = 114{\cdot}7$, we obtain the following results, expressing the number of foot-pounds of work required to compress one pound of air under each of our three suppositions:—



	Foot-pounds.
1. Isothermal compression....	56,927
2. Single-stage	70,383
3. Two-stage	63,179

In other words, compared with the ideal of isothermal compression, the work expended in single-stage compression is 23 per cent. more, and in two-stage compression only 11 per cent. more, a clear saving of 12 per cent. There is no doubt an additional saving in two-stage compression, arising from the fact that the average temperature of each of the cylinders must be lower than when all the work is done in one cylinder. The author does not know that this saving has been calculated, or taken note of; but it is evident that as the range of pressures is less, so must be the range of temperatures, and therefore, also, *cæteris paribus*, the average temperature. This saving is in a certain way analogous to the advantage gained in steam engines by expanding the steam in two separate cylinders, and so preserving the average temperature of each as nearly constant as possible, with this difference, that in the present case we wish to keep both cylinders as near the lower temperature as possible. In order to prevent jar, and at the same time to enable compressors to be run at a much higher speed, mechanically controlled valves are used by several inventors, notably by Professor Riedler, of Berlin, in whose compressors the air valves open automatically, but are closed by mechanism. Professor Riedler's large compressors at Paris have been made the subject of elaborate experiment, from which it appears that with two stage compressors, an efficiency of 89 per cent. can be obtained. In one case of a Riedler two-stage compressor, the steam cylinders are 23 and 37 inches diameter, and the air cylinders 23 and 36 inches diameter. The stroke is 48 in., and the capacity, at 75 revolutions, 4,230 cubic feet per minute.

The conveyance of the air from the compressor to the interior of the mine does not require any special description. If moderately large pipes are used, so that the velocity of the air does not exceed 20 to 30 feet per second, the air may be conveyed to long distances, even several miles, with very little loss of pressure. There ought also to be no trouble from leakage

if the joints have been carefully made in the first instance; for the temperature of a mine is so uniform that there is no appreciable expansion and contraction of the pipes. Compressed air is *par excellence* the medium for driving reciprocating tools, such as rock drills and coal-cutters of the percussive type. A high degree of efficiency is not expected in machines of this class. They are made as small and light as possible, and work with a low grade of expansion. But compressed air has also long been used for driving hauling engines and pumps, especially when these are of an auxiliary character only, and placed at long distances from the shafts. Whether electricity will eventually supplant compressed air is a question which it is impossible to answer at present. Attempts to improve the efficiency of compressed air by using stoves to heat the air have proved successful in applications above ground, but the additional complication and risk have hitherto prevented similar appliances from finding favor in mines. Expansion of the air in two stages is another way in which its efficiency can be improved, but very few applications of this method have yet been tried.

The electric transmission of power differs in one respect from the system already described. No serious damage is done to a hydraulic or compressed-air engine, if through any cause the load or work to be done suddenly becomes greater than the normal amount. But an electric motor, unless proper provision has been made, becomes unduly heated and is liable to be rendered unserviceable. The obvious way of preventing such a mishap is to insert a fuse or magnetic cut-out in the circuit. But when such safeguards come too readily into action, great inconvenience may arise from frequent interruption of the work. When, however, a motor is considerably larger than is actually required for the normal amount of work, it will not be injured so readily by overloading, and it will not be necessary that the cut-out appliance should come so readily into action. Accordingly, the most up-to-date makers recommend an ample margin between the power of a motor and its normal work. As an example of this we may cite the following recently-erected plant at Ashington, Northumberland. It is entirely a pumping installation, and we give, in the case of three different sizes of three-throw pumps, the effective horse-power of the electric motor, and the actual horse-power required to lift the water.

Motor.	Pump.
120	70
25	14
11½.....	3

But although it is expedient to allow a margin of 50 per cent., or even 100 per cent., between the effective horse-power of a motor and the work which it is intended to do, this does not imply any such discrepancy between the power expended and the power utilized. The efficiency of a well-designed continuous-current plant for pumping may be judged from the following figures founded on the experience of an expert and manufacturer of such machinery. Starting with a steam engine of 100 indicated horse-power, the generator will develop 87. The loss in the cable of course depends on the distance, but under ordinary circumstances we should have 82½ horse power delivered at the motor, and the motor ought to yield 70 horse power in useful work. Thus the aggregate efficiency of the whole installation may be taken at 70 per cent., a result which compares favorably with either of the two systems described above. Electricity has not up to the present been so successfully employed for driving percussive tools, and it remains to be seen whether it will eventually supplant compressed air for this class of work.

The advisability of introducing any form of electric transmission into the inner workings of collieries which give off explosive gas or are largely permeated by explosive dust, is a question which has engaged the anxious attention of mining engineers. It is here that the induction motor possesses a distinct advantage in consequence of its entirely sparkless character. No doubt many continuous-current motors are in use which are wholly enclosed within an airtight casing. Such motors require to be made of about 30 per cent. larger size than open running motors designed for the same work, in order to make allowance for the extra amount of heating which the absence of ventilation entails. As a protection

against injury from dust the closing of the motor may be excellent; but we doubt whether it can be considered a sufficient remedy against the risk of a possible accident in the case of a motor running in an explosive atmosphere. It is sometimes said that an explosive atmosphere ought not to exist in any mine, but those who make this observation may not be aware that there are many mines which are liable to sudden outbursts of gas which, for a time, render the whole mine explosive. A derangement of the ventilating machinery is another cause which may render the best ventilated mine dangerous for a time. In addition to the danger from sparks at the commutator of a continuous-current motor, there are other possibilities of danger which apply to both the continuous current and to the three-phase system of transmission. These arise from the burning out of the insulation, or the rupture of a cable. Heavy falls of the roof are matters of the most ordinary occurrence in mines, and it is at least conceivable that such an accident might rupture the cable and produce sparking. This risk is perhaps preventible by proper precautions, and appears more remote than those previously mentioned.

It has been proposed that for the class of mines of which we have been speaking, electrically driven air compressors might be established in parts of the mine where there is hardly any risk of the atmosphere ever becoming explosive, in order that power might be transmitted safely into the more dangerous inner workings. Where the distance of transmission is exceptionally long, or where electric current is already available, this arrangement may be quite feasible. But the principal losses incurred in the employment of compressed air occur at the compressor and at the motor, and not in the course of transmission along the pipes. It therefore would seem an unnecessary complication to convert the energy of a steam engine first into electric energy, then to transform it into the energy of compressed air, when the air might just as well be compressed by the steam engine, and conveyed with hardly any more loss from thence to the point at which it is required.—*The Colliery Guardian.*

Efficiency Test of a Nordberg Air Compressor at the Burra Burra Mine of the Tennessee Copper Company.*

BY J. PARKE CHANNING.

This compressor, which is of the cross-compound two-stage type, is located in a brick power house, together with a first motion hoisting engine and an independent jet-condenser. An adjoining brick boiler-house contains two 150 horse-power National water tube boilers, which furnish steam for the above-mentioned engines as well as a 9 and 18 by 12-inch crusher house engine. The compressor and the crusher house engine run condensing while the exhaust from the condenser itself as well as part of the intermittent exhaust from the hoisting engine are carried to a large Hoppes open feed-water heater. The balance of the exhaust steam from the hoisting engine is discharged into the atmosphere. Steam has never been off the jackets of the hoisting engine cylinders since first turned on. These cylinders are jacketed, not from motives of economy, but to make the hoisting engine quick to respond to the throttle. All the auxiliary cylinders of the hoisting engine are steam-jacketed.

The test was made on Sunday. During this time, the boilers, which could not be separated, furnished steam for the hoisting engine jackets and the independent jet-condenser as well as the compressor. The crusher engine was not running nor was the hoisting engine.

The makers' guarantee was that the steam consumption would be 14 lbs. per indicated horse-power when running at full speed, 92 revols. per min., and that the ratio of 1 h. p. between the steam and air cylinders would be as 115 to 100, or 87 per cent. No guarantee as to efficiency of the air end as a compressing mechanism was given.

In determining the feed-water consumption the engine was to be charged with all water fed to the boilers during the test, including that used in the steam-jackets. The engine was to be credited with all water trapped from the steam

* Paper presented at the annual meeting of the Lake Superior Mining Institute, 1902.

separators and indicated by the calorimeter test of the steam from the separator into the cylinder. The engine was further to be credited with whatever heat was contained in the water formed by condensation in the steam-jackets and reheaters.

The test was made under the supervision of Mr. C. H. Glasser, the mechanical engineer in charge of the construction of the Tennessee Copper Company's mine and smelter plant. Feed-water was taken by feed-pump from a square wooden tank in the boiler-house and water supplied to the tank from two barrels placed on scales set over the tank. No allowance was made for the small amount of steam necessary to operate this pump. Condensation from steam-jackets and reheater of the compressor was drawn off continuously into two barrels partly filled with cold water and set on scales, one barrel filling while the other was discharging. The height of water in the piping system was regulated throughout the test by a gauge glass inserted in an enlarged chamber of 6-inch pipe and thermometer attached, to record the proper temperature of the water. The thermometer reading was taken always when the barrel was nearly full or when the circulation had been continuous for the longest possible period of time. The condensed water from the hoisting engine jackets passed through a steam trap to a barrel partly filled with water and set on scales. The discharge was intermittent with the working of the trap. The steam used for running the condenser was exhausted through coils of pipe laid in a shallow wooden tank and constant circulation of cold water maintained in the tank, thus condensing all the exhaust steam, which was led into barrels and measured. Each barrel being always filled to an exact height, the capacity of the barrels to that height was found by weighing before and after the test. The slip of air was calculated from the relation of the total length of indicator card to the length of card on the atmospheric line.

The theoretical horse-power required to compress and deliver the actual delivery of air by adiabatic compression was calculated from the formula on page 501 of Kent:

$$W = 3.463\ p_1 v_1 \left\{ \left(\frac{p_2}{p_1} \right)^{0.29} - 1 \right\}$$

in which p_1 is 14 lbs., p_2 is 79.3 + 14 = 93.3 lbs. and v_1 equals 1,976.7 cubic feet.

The theoretical horse-power by isothermal compression was calculated by the formula,

$$W = p_1 v_1 \left\{ 1 + \text{Nap. log.} \frac{p_2}{p_1} \right\}$$

The results of the test are given in the accompanying tables. The governor pulley was not the right size, and so the speed maintained was only 90 instead of 92 revols. per min. The inter-efficiency between the steam and air cylinders—95.1 per cent.—is high, and this figure was borne out in another test of the compressor. The efficiency of the machine—78.1 per cent.—is also remarkably good.

It may be interesting to reduce the figures of this compressor as well as two other Nordberg machines to the basis of pounds of feed water used per 100 cubic feet of free air compressed and delivered at 80 lbs. gauge pressure.

Newport Mine, compound, two-stage .....3.87 lbs.
Leonard Shaft, triple, three-stage.3.10 lbs.
Burra Burra Mine, compound, two-stage .....3.68 lbs.

The above figures are reduced to a basis of 80 lbs. gauge pressure, as the Newport compressor was tested at 100 lbs. and the Leonard at 90 lbs.

Particular attention is called to the efficiency of the cooling arrangements and the relatively low temperature of the finally discharged air. All the air valves of the compressor are positively operated, being in construction and connection similar to the exhaust valves of an ordinary Corliss engine, there being no trip or release on any of them. The discharge valves of the compressing cylinder are provided with auxiliary poppet valves, which would open in case the receiver pressure was lower than that at which the main valve would begin to discharge. The governor for this compressor is one especially designed by Mr. Nordberg for work of this class, and consists essentially of a floating lever. The three forces which operate upon it are the steam pressure, the air pressure and the speed of the machine. This governor is so designed that it maintains a constant

EFFICIENCY TEST OF NORDBERG CROSS COMPOUND TWO STAGE AIR COMPRESSOR. BURRA BURRA MINE.

Results of Indicator Cards.

Indicator Card.	Time Taken.	Revs. per Minute.	Mean Effective Pressures. H. P. Steam.	L. P. Steam.	L. P. Air.	H. P. Air.	Indicated Horse Powers. L. P. Steam.	H. P. Steam.	Both Steam Cylinders.	L. P. Air.	H. P. Air.	Both Air Cylinders.
1	10.45 a.m.	90	45.74	13.26	16.26	38.24	155.14	136.52	291.66	144.76	131.40	276.16
2	11.45 a.m.	91	48.90	12.64	16.16	40.70	149.53	147.51	297.04	145.06	140.41	285.47
3	12.45 p.m.	90	47.17	12.64	16.18	38.18	147.89	140.78	288.67	144.05	131.39	275.44
4	1.45 p.m.	90	48.0	13.04	16.33	39.94	152.56	143.26	295.82	145.21	137.24	282.45
5	2.45 p.m.	87	48.04	12.86	16.16	39.45	145.44	133.86	279.30	138.90	131.04	269.94
6	3.45 p.m.	91	48.92	12.97	16.18	39.35	153.43	147.58	301.01	145.24	136.72	281.96
7	4.45 p.m.	91	47.88	13.82	16.34	40.81	163.49	144.44	307.93	146.68	141.78	288.46
8	5.45 p.m.	88	45.04	13.70	16.15	38.75	156.73	127.01	283.74	140.41	130.19	270.60
Averages							153.03	140.12	293.15	143.79	135.02	278.81

air pressure in the receiver, permitting the variation of the steam pressure as well as the speed of the engine. In other words, whether there be ten or twenty drills running, the air pressure in the receiver will remain practically constant and the speed of the engine will vary to suit the demand for air. This variation of speed is, of course, made by varying the cut-off point on the high-pressure steam cylinder. In practice this governor has been found to be entirely satisfactory, and is a great improvement over the older types which were more or less intermittent in their action, even if otherwise satisfactory.

RESULTS OF CALORIMETER TESTS WITH PEABODY'S THROTTLING CALORIMETER.

Readings Taken.	Temperature Fahr.	Calorimeter Gauge.	Steam Pipe Gauge.	Per cent. Moisture Calculated.
4.30 p. m.	294	11	145	1.23
4.35 p. m.	294	11	145	1.23
4.40 p. m.	296	15	145	1.34
4.45 p. m.	296	15	145	1.34
4.50 p. m.	296	14	145	1.35
Average				1.3

TEST NO. 3, NORDBERG TWO STAGE AIR COMPRESSOR AT BURRA BURRA MINE. ALTITUDE 1,800 FEET.

1	Date of Test	Feb. 16, 1902.	
2	Duration of Test	8 hours.	
3	Diam. of High Pressure Steam Cylinder (Steam Jacketed)	14	inches.
4	Diam. of Low Pressure Steam Cylinder (Steam Jacketed)	28	inches.
5	Diam. of Low Pressure Air Cylinder	24½	inches.
6	Diam. of High Pressure Air Cylinder	15⅜	inches.
7	Stroke of All Pistons	42	inches.
8	Diam. of Piston Rods	2¼	inches.
9	Revolutions of Engine, Average per Minute	90	
10	Piston Speed per Minute.	630	ft.
11	Steam Gauge Pressure, Average	145.9	lbs.
12	Temp. of Steam in Steam Pipe, Average	364	°F.
13	Steam Pressure in Reheating Receiver, Aver.	8	lbs.
14	Vacuum in Condenser, Average	25.66	inches.
15	Air Pressure in Intercooler, Average	22.63	lbs.
16	Air Pressure in Receiver, Average	79.3	lbs.
17	Temperature of Air at Intake, Average	65	°F.
18	Temperature of Air Leaving Low Pressure Cylder, Average	211.5	°F.
19	Temperature of Air Leaving Intercooler, Average	78.5	°F.
20	Temperature of Air Leaving High Pressure Cylinder, Average	240	°F
21	Indicated Horse Power in High Pressure Steam Cylinder, Average	140.12	
22	Indicated Horse Power in Low Pressure Steam Cylinder, Average	153.03	
23	Indicated Horse Power in Both Steam Cylinders, Average	293.15	
24	Indicated Horse Power in Low Pressure Air Cylinder, Average	143.79	
25	Indicated Horse Power in High Pressure Air Cylinder, Average	135.02	
26	Indicated Horse Power in Both Air Cylinders, Average	278.81	
27	Feed Water Weighed to Boilers	43,343	lbs.

28	Reheater and Jacket Water from Compressor, Weighed	4,081	lbs.
29	Average Temperature of Reheater and Jacket Water	356.7	°F.
30	Total heat in 1 pound of Steam at 356.7 deg. F.	1,190.7	H.U.
31	Total Heat in 1 pound of Water at 356.7 deg. F..	328.9	H.U
32	Equivalent Credit for Reheater and Jacket Water	1,127	lbs.
33	Water Weighed from Condensation in Hoisting Engine Jackets	1,781	lbs.
34	Steam Used to Run Condenser	4,320	lbs.
35	Total Credits to Feed Water	7,228	lbs.
36	Total Feed Water charged to Engine	36,115	lbs.
37	Moisture in Steam Shown by Peabody Calorimeter.	1.30	%
38	Credit for Moisture in Steam	473	lbs.
39	Total Steam Charged to Engine	35,642	lbs.
40	Dry Steam per Hour Charged to Engine	4,455	lbs.
41	Steam Consumption per Indicated Horse Power per Hour	15.19	lbs.
42	Guaranteed Steam Consumption per Indicated Horse Power per Hour, at 92 rev. per min.	14.00	lbs.
43	Excess of Steam Consumption per Indicated Horse Power per hour over Guarantee	1.19	lbs.
44	Theoretical Delivery of Free Air per Minute at 90 Revolutions	2,037.8	cu.ft.
45	Slip of Air (Percentage).	3.0	%
46	Actual Slip of Air per Minute	61.1	cu.ft.
47	Actual Delivery of Free Air per Minute, Average	1,976.7	cu.ft.
48	Theoretical Horse Power Required to Compress and Deliver Actual Delivery of Air at Receiver Pressure by Adiabatic Compression	306.53	
49	Theoretical Horse Power Required to Compress and Deliver Actual Delivery of Air at Receiver Pressure, by Isothermal Compression	229.0	
50	Actual H. P. Shown by Air Indicator Cards...	278.81	
51	Actual H. P. Shown by Steam Indicator Cards.	293.15	
52	Actual H. P. Consumed by Friction of Engine.	14.34	
53	Efficiency Ratio Between Steam and Air Cylinders	95.1	%
54	Efficiency Ratio Between Steam and Air Cylinders Guaranteed by Builder.	87	%
55	Efficiency of Machine, or Ratio of Steam I. H. P. to Theoretical Air I. H. P. Isothermal Compression	078.1	%

Building a Tube.

IN THE SUB-AQUEOUS SECTION OF THE BAKER ST. LINE, LONDON.

With the appearance of the tuppenny tube most people are familiar, though there are some folks who still pride themselves on refusing to travel by the electric railway, whose developments are being so closely watched by all sorts and conditions of men whose avocations make rapidity of transit and an easy method of going to and from their places of business an imperative necessity.

The tube, however, in its incomplete stage is a subject with which few people can in the nature of things have a personal acquaintance, for the work has to be done unhampered by the presence of curious sightseers. Still, as a special favor a representative of the *Morning Leader* was recently allowed through that section of the Waterloo and Baker St. railway which is building.

Access to the tube is gained from the landing stage in the middle of the river by Hungerford bridge, under the shadow of Charing cross. There one enters an iron cage to be hoisted many feet and swung round the arc of a circle, over the circular opening down which one is lowered, to the accompaniment of the rattle of the engine, the sixty or seventy feet which intervent between the outer air and the road-bed through which, in the course of perhaps a couple of years, there will roll an unceasing line of traffic.

The work is at present being conducted under two different systems. One of these is under ordinary conditions of atmospheric pressure, while the other is "in the air," to use the term the men themselves apply to it. This is under an additional pressure of ten pounds to the square inch, and it is obtained by pumping compressed air into the works. It need hardly be said that in order to obtain this additional pressure the air has to be confined within a certain area. This is done by the construction of a lock which acts in exactly the same way as the familiar locks on the river. A lock is in a brick wall some eight feet thick, with a door at each end. That at the farther end opens out of the lock into the tunnel, while

the inner door opens the other way. They are so arranged, however, that both cannot be opened at once. If workmen have to go "into the air" the lock is filled with air, and when the required pressure is obtained the far door opens and allows them to enter the works; while, when they desire to leave, the process is reversed, the pressure is removed, and the inner door opens.

No visitor is allowed in any part of the works being conducted under this additional atmospheric pressure without having previously undergone a thorough medical examination, and the same precautions are taken with the workmen. On first going "into the air" one can hear the air rushing into one's ears, and some people feel the pressure against the ear-drum, but there is no oppression on the chest, and no difficulty in breathing. Occasionally, however, the pressure on the ear becomes quite a pain, and men have been known to cry aloud from it, while another effect is to take away their appetite. The men who work under this increased atmospheric pressure have only an eight hours day, while the other laborers work twelve hours.

The compressed air is brought down in a pipe running along one of the walls of the tube, and by its side is a smaller pipe for conveying water which is needed for mixing the cement with which the iron skin of the tube is filled to a depth of six or seven inches. A section of the tube would show in addition to the two pipes at the side two wires which run over head suspended by means of transverse wires. One of these carries the current for the lamps with which the tunnel is lighted throughout its whole length at equal distances of about seventy feet, while the other carries the current for propelling the little electric engines which draw a train of metal boxes. Into these the earth is loaded as it is dug out, that it may be taken down to the river, where it is hoisted out, loaded into barges and taken out to sea and thrown away. On the return journey the same boxes convey sacks of cement and other building materials to the places where the men are working.

The rails on which the engines run are close together, perhaps between twelve and eighteen inches apart. By the side of them is a narrow footpath formed, for the most part, of three ordinary boards laid side by side so that though two men could hardly walk abreast they may easily pass one another. Lighted though it is by electricity, the tube can scarcely be said to be brilliantly illuminated, and as the little engines run rapidly and smoothly along, the play of blue fire from the wire above and the rails below gives a distinctly uncanny suggestion to the twilight gloom which fills the tunnel, for it is not a bit like lightning flashing through the storm-driven, clouded sky, but suggests rather the "ineffectual fires" of some unknown inferno. As one pauses in the tube one begins to appreciate the meaning of the word silence, the dread soundlessness that might exist in a city of the dead, intensified by the feeling of having been cut off, as it were, from all the rest of the world. Yet, ever and anon, at certain places on the way the distant sounds of traffic come mumbling and rumbling down as if to assure the passer-by in these unfrequented regions that life still takes its hurrying way along the street some sixty feet above his head.

Occasionally, as one tramps along the narrow pathway, one comes upon a hole left in the side of the tube to enable the platelayers to go from one tunnel to the other, for in the tunnel now building, as is the case in the familiar tuppenny tube, the down trains will run in a different compartment from the up trains, so that the possibility of a collision is removed. These tunnels are, in some cases, extraordinarily close together, being separated, at a junction, by perhaps not more than an inch and a half of material, though they diverge until they may be as much as five feet apart. At intervals along them, too, one comes upon ledges on which the engineers may place their instruments while they are making observations, while here and there from the iron roof depend little stalactites formed by water percolating, from the clay through which the tubes are run, through the partition between two of the iron segments of the tube, after having dissolved the layer of cement which is pumped in between the earth and the metal skin of the tube. Here and there, too, one notices sleepers, which have been removed from the track because the damp

has rotted them. These damp places, however, are only noticed by their contrast with the general dryness of the tube, and it will be quite easy to completely eradicate them when the time comes, even though it were possible for the moisture to make its presence felt through the layer of encaustic tiles with which the tube will be lined from end to end. At present, however, that work has not been begun, though it has been thought of, for at one spot between Picadilly-circus and Oxford St. several different sorts of tiles have been put in order to try their effect.

At Oxford-circus the same sort of cage is to be found as at the river stage with a cable chain and a donkey engine to run it. The engine, however, is not kept working all night and day, though laborers are engaged in the tube every hour of the twenty-four. That they may leave at Oxford St. instead of having to go back all the way to Charing cross when their work is finished, ladders lead from the tube to the level of Oxford St. To prevent the possibility of any accident there is not one long ladder, but four short ones set against platforms which form convenient resting-places, so that even the least skilled climber may go from tier to tier without fear and with perfect safety.—*Morning Leader,* London.

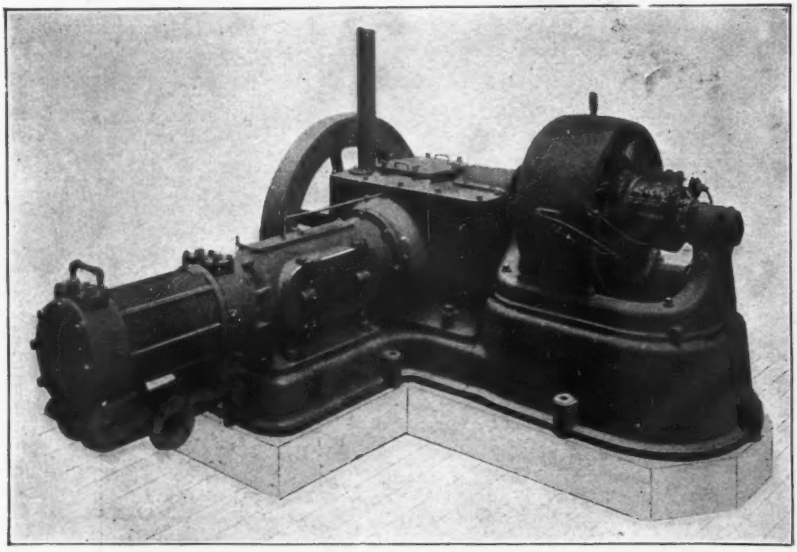
Rock Boring Machinery.

Exactly 50 years ago Piatti proposed the use of compressed air in the construction of the Mont Cenis tunnel, and it is interesting to consider the far-reaching effects on the mining industry of this suggestion, which at the time was received with indifference. Undoubtedly the most important result has been the introduction of boring or drilling machines as substitutes for the older method of hand boring. for although the merit of devising and using the first machine for drilling rocks belongs to Richard Trevithick, his invention was forgotten until the Mont Cenis experiments showed that compressed air was more suitable than steam as motive power for such machines. Since then inventions have followed one another with rapidity, and there has been an astonishing development of this class of machanism. Bartlett's rock drill was tried at Mont Cenis in 1854, and in the same year Schumann invented his percussion power drill. Sommeiller's drill was invented in 1857. In 1861 Lisbet applied his boring machine in soft rock. The Sachs drill was invented in 1863; the Burleigh drill in 1866; the Doering drill in 1867; the Dubois and Francois drill in the same year; the diamond drill in 1870; the Ferroux drill in 1873; and the Darlington drill in 1873. Since that time to the present inventors throughout the world have applied themselves to the production of modifications which should accomplish more easily the intended object. In the earlier forms the machines were exceedingly heavy, especially in the supporting arrangements, which were planned for keeping two or more machines at work simultaneously. The adoption of smaller and lighter forms, of which the Little Vixen, the Little Hercules, the Ingersoll-Sergeant, Schram, Champion, Holman, and Larmuth drills are typical modern examples, has done much towards popularizing their use in mines. The advantage of a machine driven by compressed air for ventilating workings is so obvious that the use of hydraulic power, which has been successfully applied in the Brandt rotary drill, has met with but little favor in mines. On the other hand, electricity is now beginning seriously to compete with compressed air for transmitting power to drills, and after the 50 years' sway of compressed air it is a matter of no little difficulty for a mining engineer in the year 1903 to say which of the numerous admirable rock drills on the market it would be best to adopt in a mine entrusted to his charge. The Brandt drill, with which remarkably fast work can be done, is very costly to install. Its consumption of power in enormous, and the necessary repairs expensive. This machine is consequently only suitable for use in tunnels of the highest class. Electric drills have met with great favor in the Cleveland iron ore mines, and the electric drill described by Mr. Edward Dane (*Mining Journal,* 1902, p. 187) and that used for stopping at the Battery Reef Mine of the Lancaster Gold Mining Company described last year (*Mining Journal,* 1902, p. 516) appear to present distinct advantages. Indeed, in view of the advantages of electricity over compressed air as a medium for transmit-

ting power, there are many who believe that the days of the compressed air drill are numbered. Apart from the loss of power, the long rubber hose is an undoubted inconvenience. No such drawbacks are presented by electric transmission. All local difficulties can be overcome and the cable occupies hardly any space and can be laid with ease and rapidity. On the other hand the percussive electric drill necessitates frequent and costly repairs, and the mechanism is of a complicated character. In an account of his experience with electric drilling at the Raibl mines, the eminent Austrian mining engineer Von Posch notes that the drill used consisted of 330 distinct parts, as compared with 40 or 50 in a compressed air drill, and that during the period from March to November, about three-quarters of a year, there were 186 breakages, or about one a day, whilst Mr. T. Giller records that four compressed air drills working simultaneously at the end of a crosscut were used for many weeks without the expenditure of a penny for repairs. The solenoid drill, although requiring much more power, is far more portable and lighter than the electric percussive drill. A solenoid, it will be remembered, consists of insulated copper wire coiled in the form of a spiral, with an iron core movable, not fixed as in an ordinary electro-magnet. When a current passes it has the same power of attraction as a magnet, and the iron core is drawn up. In a solenoid drill two solenoids are placed against each other, and the electric current imparts a reciprocating motion to a magnet to which the drill piston is fixed. This machine necessitates a special primary motor. The most serious drawback presented by the solenoid machine is the objectionable heating. This not only means loss of efficiency, but the heating is often so intense as to make the drill unpleasant in a narrow level or to cause risk of accidents from burns. Large quantities of air are necessary for ventilation and the loss by friction is high as the lubricants are volatilised. In short, practical experience tends to show that electricity has as yet hardly fulfilled the expectations as regards the transmission of power to rock drills. The chief reproach to which the compressed air drill is liable is its high consumption of power. Published figures show that the indirect-acting percussive electric drill requires 1½ to 2 horse power, the solenoid drill 4 to 5, and the compressed air drill 5 to 11 horse power, according to the size of the compressor. Apart from this drawback, which after all is not so serious to the miner, to whom speed of driving is frequently the first consideration, as might at first appear, all the advantages are on the side of compressed air. The question which type of rock drill (electric, hydraulic or pneumatic) is best to use is nothing more than a question of power transmission, which depends upon the natural resources and local conditions and upon the physical properties of the medium of power transmission. Probably the best solution of the whole question is to be found in a combination of electric power transmission with the compressed air percussive drill. This combined system, as was evident from the display at the recent Düsseldorf Exhibition, is meeting with great favor in Germany. The system consists in conveying by cables to the vicinity of the working place electric energy generated at a convenient spot. The electrically-driven high speed compressor is placed at the mouth of the tunnel, or is made movable and brought within 100 yards of the mine working. An installation of this kind was put in operation in the spring of 1902 at the Friedrich Wilhelm mine in Upper Silesia. In the first month, with two light drills (2½ inches in diameter), 1620 feet were bored in 5700 minutes (including time of seting up), or in other words 1 yard in 10½ minutes. The ground consisted of sandstone and shale with ironstone nodules. The electro-motor was of 13 horse power, and the two drills, at six atmospheres pressure, required only 5 horse power, or at five atmospheres only 4½ horse power. A Meyer high speed compressor was used, so arranged that a 25 horse power air compressor with motor and accessories could be placed within the cross section of a mine wagon. The length of the whole was only 7¼ feet, the height 3¼ feet and the width 37½ inches. A whole series of such high speed portable compressors was shown at the Düsseldorf Exhibition, and the conclusion impressed on the observer was that in a rational combination of electricity and compressed air the future of rock boring installations is to be sought.—*Mining Journal,* London.

Motor Compressor.

The accompanying illustration represents a type of motor compressor used by the American Compressed Air Cleaning Co., in connection with their work, built in sizes from 50 cubic feet of free air per minute and upwards. In the design of this compressor is embodied the desirability of having all the working parts enclosed so as to exclude dirt and grit. The chamber so formed contains oil with which all the working parts



are automatically and continuously lubricated, including the cylinder, which is connected with the oil chamber in such a manner that the proper quantity of oil for lubricating the surface between the cylinder and piston is automatically supplied, so that no sight feed lubricator is required. The machine will remain lubricated as long as the main supply of oil in the well is maintained up to a level determined by a filling plug on the side of the crank chamber. The piston rod passes through a specially constructed metallic packing box, which is self-adjusting and will last for many years without attention or renewal, on account of the perfect lubrication of the piston rod, as well as its superior mechanical construction. The piston is provided with an improved form of packing rings, which are carefully fitted in place, both in the piston and against the surface of the cylinder so as to form a nearly perfect sliding joint. The cylinder is of extra quality close grained cast iron, accurately and smoothly bored, free from blow holes and defects, and is together with the valve heads, thoroughly water jacketed.

The extended end of the crank shaft is provided with a gear which meshes with a pinion arranged on the armature shaft immediately above. The gear chamber and the crank chamber are connected in such a way that the gear as well as the pinion are operated in a bath of oil, which oil is also supplied automatically to the bearings at the pinion end of the motor. The gear and pinion are of the helical herring-bone type, with teeth cut by special machinery in the most perfect manner, thereby reducing the noise of operation to such an extent that it can hardly be noticed alongside of the ordinary operation of the compressor valves. The motor is of the series wound type with formed coils of the most improved

pattern, the insulation and other material being of the very highest grade of their respective kind. The material and labor of this motor are of such excellent quality that we are able to start the compressor without using resistance in the motor circuit, by simply closing the motor circuit in the same manner as with a knife switch.

FIG. 1.

House Cleaning with Air.

In Fig. 1 we see dust laden hangings, shaking off their accumulations at every breeze or touch, and polluting the air about them. Heretofore, it has been necessary to take them down when cleaned, and this with the rehanging and redraping often cost more than the cleaning, besides incurring more or less worry and bother. With compressed air they may be cleaned where they hang, without material disarrangement of their folds, with absolutely no wear to the fabric and with little expense—therefore cleaned often.

Chalk is a difficult thing to remove from billiard cloths; and, besides, it is wearing to the fabric. Fig. 2 illustrates a stiff brush in the hands of a strong boy, and the cleaning is accomplished within a few minutes.

The Portable Compressed Air Cleaning

Apparatus used in this work by the American Compressed Air Cleaning Co., consists of a strong well built wagon upon which is mounted a gasoline engine, air compressor, air reservoirs, cooling tank, hose, nozzles, cleaning machines, etc.

Two styles of wagons are built: i. e., self-propelling and draught, both being equally efficient except that a team is required to move the latter from house to house.

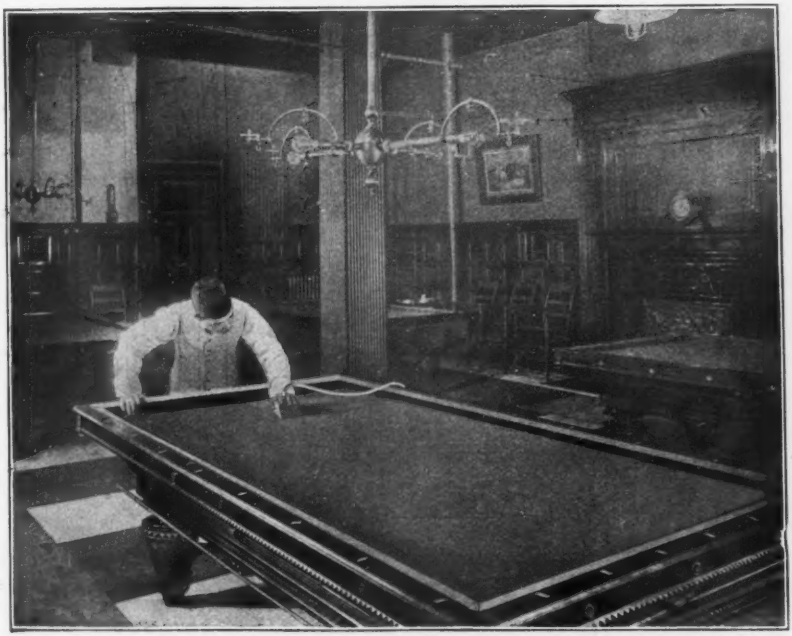


FIG. 2—COMPRESSED AIR BILLIARD CLOTH CLEANER IN OPERATION.

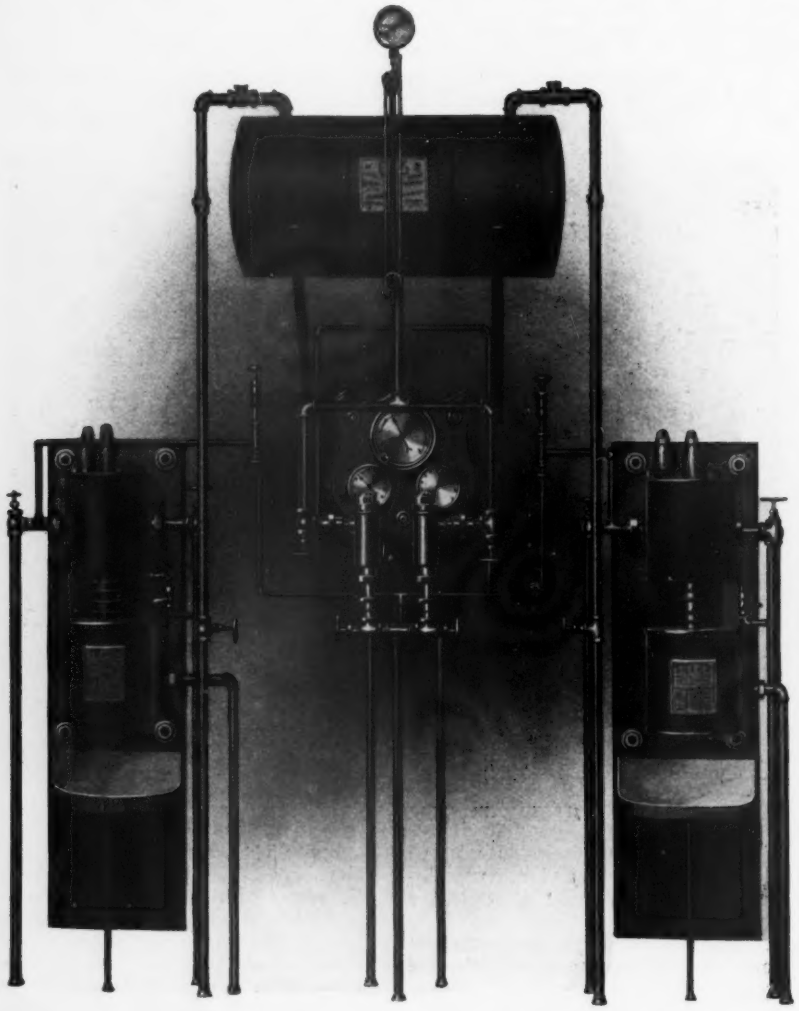
These wagons are admirably adapted for cleaning residences and other buildings too small to require a stationary plant.

One wagon manned by two competent workmen and an apprentice will clean a ten room residence in a day.

Pneumatic Lubricator.

The accompanying illustration shows the plant as it appears above the floor line. Beneath the floor there is a ten-barrel receiving tank into which the oil is run in the first place. In connection with the system there is an air receiver, located beneath the engine room into which air to operate the system is compressed, as for example, up to 60 lbs. From the receiver to the original tank there is a pipe line which admits air pressure to force the oil up into the tank above the engine room floor. On top of the original receiving tank a filter is connected up to said tank with a check valve between. The return oil from the sole plates of the engine is conveyed to the filter through piping and percolates through the same by gravity into the original receiving tank. The filter is protected from any pressure by the check valve before mentioned. An equalizing valve between the receiving and distrbuting tank as illustrated shows that any desired pressure can be kept thereon beneath the distributing tank. There are two filters, one can be cleaned while the other is in operation, and two Westing-

house or similar air compressors, one or both can be used according to requirements for such purposes as cleaning of switch board dynamo, or as is often done



whitewashing the basement, pipes for which are taken from the receiver to any desired point of the plant. It is a well known fact that in many places an elevated tank is used for a gravity system. The oil must be pumped up from below to those tanks and the gravity system is intermittent regardless of the head. With the present system, no matter how slight, the feed is constant, a system, such as this, will take care of every bearing on any job regardless of how extensive the case may be. The saving of the oil is not taken into consideration, that is

thrown in as a bonus. Mr. Young, who installed the B. & O. tunnel electrical generating plant, writes that he is saving $300.00 a month on labor alone.

This pneumatic lubricating system is the invention of Mr. J. F. Pilling, general manager for the Port Huron Air Tool Co., Ltd.

Dake Pneumatic Chain Hoists and Air Motors.

Descriptive Circular No. 6, received from the Dake Engine Co. of Grand Haven, Michigan, illustrates their Pneumatic Chain Hoists and Air Motors.

We show in Fig 1 the pneumatic chain hoists manufactured by this company. This hoist is made along the line of the standard hand chain block, to which is attached the Dake reversing air motor. The hoist is simple in construction, durable and efficient. It is operated by pendent hand chains as shown in illustration, and will sustain the load at any point. This class of pneumatic motor hoist is meeting with a very favorable reception from manufacturers of heavy machinery, and is especially adapted for serving heavy machine tools and in places where it is necessary to sustain the work in one position for machine operations.

The air motor used with this hoist (Fig. 2) is of the double reciprocating square piston type, and is favorably known to the trade as a desirable motor for direct-connected work where small, compact and high speed motors are desired.

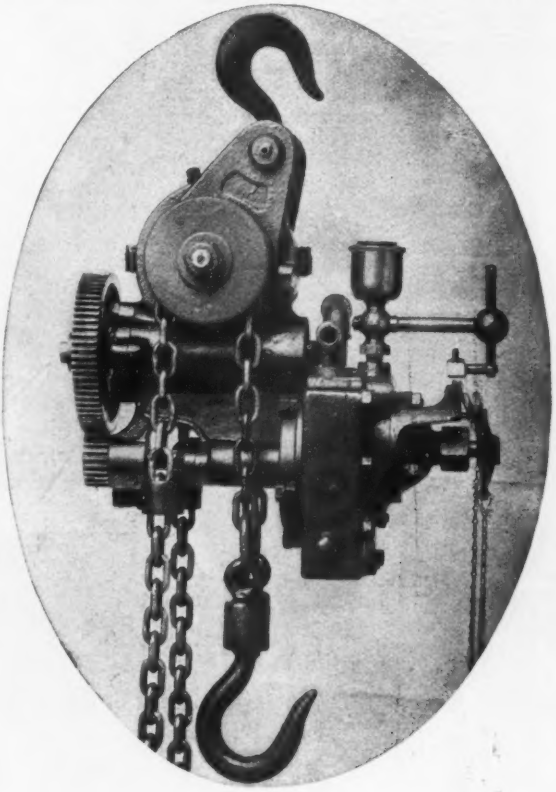


FIG. 1.

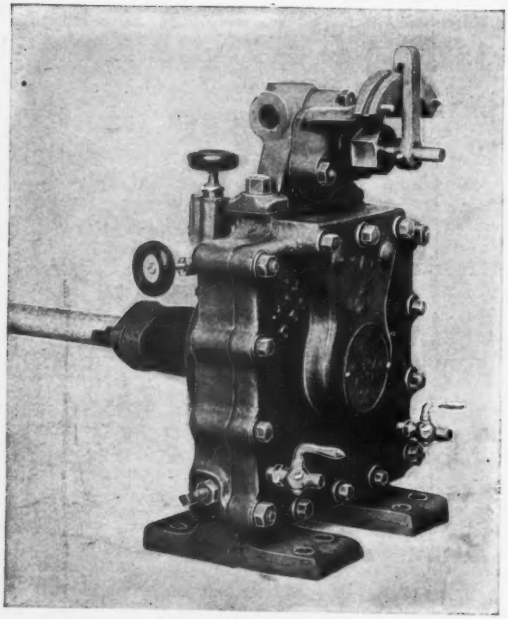


FIG. 2.

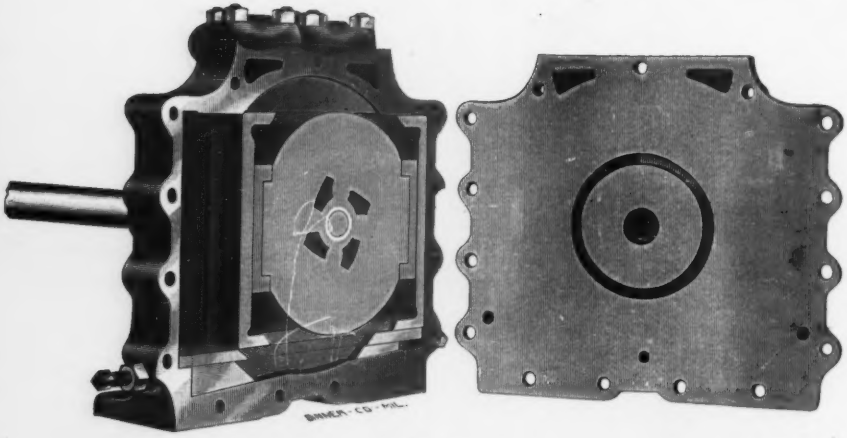


FIG. 3.

We also give in Fig. 3 the working parts of the motor. They consist of only two movable pieces, one sliding inside the other and guided in their movements by the crank on the end of the driven shaft.

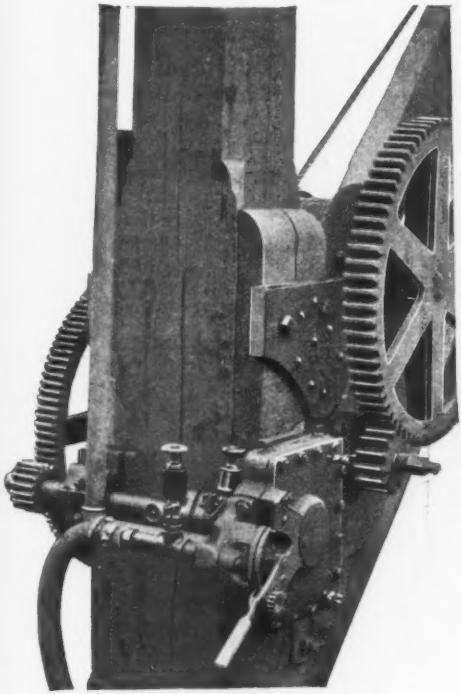


FIG. 4.

The inner piston has cored through its body four ports, leading to the four sides or ends of pistons, and which communicate with the two ports cut in cover or cylinder head of engine. In the reversing engine the air passes through the center and exhausts through the circular aperture; or when throttle is reversed, air is taken through the circular ring and exhausted through the center port. The engine can be reversed instanly by the valve lever shown on the reversing air motor.

The engine operates either with compressed air or steam, and is used for changing hand to power cranes, for direct connection to fans, blowers, centrifugal pumps, and for general hoisting engine purposes.

Low Pressure Pneumatic Signaling at Salisbury.

The above plant, on the London & South Western, which is the first large low-pressure installation in England, was put into service on Sunday, November 2. At each end of the station there is situated a cabin known respectively as the east and west boxes. These two cabins and a ground frame do all the work which formerly was done by four mechanical machines, thus saving the service of six signalmen. The ground frame is only used during the time that shunting is going on at that point, and has been rendered necessary, not on account of the distance from the east cabin, as these switches could easily be operated from there, but to meet the requirements of the Board of Trade, which demands that a man must be on the ground to attend switching operations carried out at such a distance, i. e., about 1,200 ft. from the cabin. The interlocking between the east box and the ground frame is carried out as follows: When shunting is to be done a man is sent to the ground frame, all the levers of which he finds locked in the normal position. He asks cabin No. 2 for an "unlock," which is given by pulling over the lock lever provided for the purpose and which, on being reversed, frees the king lever in the ground frame and locks up all conflicting signals and points in the east cabin. On obtaining this release the signalman at the ground frame is able to operate any of his points or signals, and when the shunting is finished and his king lever has been replaced by him to its normal position, then, and not till then, can the signalman in the east box replace his lock lever, get his indication and free his signals and switches controlled by it.

The west cabin contains a 64 lever frame of the usual type made by the British Pneumatic Railway Signal Co. Twenty-two of these levers work 30 signals, 19 are for switches and five for bolt locks between the Great Western and west box; in addition to these there are two special lock levers controlling signals operated from the east cabin similar to those for the east box and ground frame; and 16 spare spaces. The east cabin also contains a 64 lever frame, 27 of which work 32 sig-

nals, 17 are for switches, three special lock levers and 17 spare spaces.

The compressed air for working the whole of the switches and signals is obtained from one power house situated near the east cabin. There are provided here two compressors, each more than sufficient to do the work of the whole station; and one is kept as a stand-by while the other is working. A further precaution is taken by having two separate powers to drive the compressors, one compressor being driven by an electric motor run from the mains of the Electric Company at Salisbury, the other by steam from a boiler in the boiler-house adjoining. The air is compressed to 30 lbs. per sq. in. and conducted through a galvanized pipe to a receiver of 250 c. f. capacity. From thence, having been reduced in pressure to 20 lbs., to two more receivers of the same capacity situated one at each cabin, and from these latter receivers, to the cabins, switches and signals, by means of galvanized pipes. The main pipe is 2 in. in diam. and the various branches run from 1 in. down to ¼ in. diam.

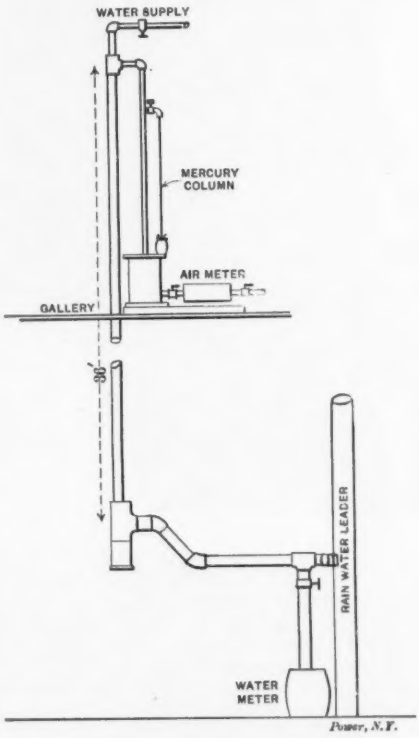
A novelty, so far as English practice is concerned, is that all the levers operating the running signals are replaced in the normal position electro-pneumatically by a valve actuated by the relay of the track circuit, with which all the running lines of the station are provided.

In several cases in this station one lever will operate one of two signals, which one depending on the position of the switch leading to the track for which these signals give permission to run on. The method of doing this is as follows: The indicator selector valve which is placed at the switches and worked by the motion plate is similar to the ordinary switch indicator valve with the exception that it is provided with extra ports. In one position of the motion plate the low pressure operating pipe A is connected, by means of these extra ports, with the low pressure pipe operating the diaphragm for signal No. 1; but when the points are moved over, the pipe A will be connected to the low pressure pipe operating diaphragm for signal No. 2.—*Railroad Gazette.*

Air Enmeshed in Falling Water.

Water, when falling freely through air or other gas, enmeshes and carries in suspension, practically, its own volume of such gas, the volume of air so carried depending somewhat upon the viscidity of the water.

That the foregoing statement is approximately true with air at atmospheric pressure is demonstrated every time a pitcher of ordinary shape is filled at a strong-



AIR ENMESHED IN FALLING WATER.

flowing hydrant. When the rising water-level approaches the relatively narrow throat, foam overflows at the brim of the pitcher and the water level remains stationary. This status continues, until the flow of water is checked to such an extent that the reduced volume of air entering in the decreased flow of water can

find room enough to escape again without commotion, when the pitcher can be filled to the brim.

The accompanying sketch shows a small experimental aspirator fastened to the wall of a building. It is provided with an air meter, consisting of a piece of pipe between stop-cocks having an internal capacity of a convenient fraction of a cubic foot. A marked barrel is placed on the ground, where it can, when required, receive and measure the descending water, while a mercury column, placed where shown, indicates the density of the air inside.

With an internal density of about one-half the atmospheric, I found that, for every cubic foot of free air entering, two cubic feet of water were measured into the barrel.

It was by no means easy to so manipulate the air admission stop-cock as to prevent the mercury column from fluctuating, but repeated trials showed the foregoing statement to be approximately correct.

Similarly, with a density of about one-quarter the atmospheric, four cubic feet of water descended; with one-eighth the atmospheric density, eight cubic feet of water descended, and so on.

With the air entirely shut off, the mercury column crawled up to 28.25 inches, which, as the temperature of the water was 80° Fahr. and the local barometer indicated 29.30 inches, was practically the water vacuum.

ARTHUR PENNELL,
in *Power*.

The Koerting Gas Engine.

The discovery of the fact that gases of low heating capacity, such as the waste gases from blast furnaces, could be used effectively, gave a great impetus to the construction of such engines, especially of large capacity. One type of engine which is now extensively used in the Koerting, which is manufactured in this country by the De La Vergne Refrigerating Machine Company, of New York. The makers claim substantial advantages for the two-cycle type, of which the Koerting engine is a representative, in comparative simplicity of construction.

This engine is the result of five years of tests and experiments on the part of Mr. Ernst Koerting, a well-known expert on all subjects relating to the gas engine. After a number of models had been constructed a 400-horse-power gas engine was built in the Koerting shops, and when it was found that this complied with all the requirements, the new engines were immediately placed upon the market, and proved very successful. The makers have already sold in the United States engines of this type, representing 41,800 horse-power.

The engine is of the two-cycle type, and is double-acting, like a steam engine, hence the crank end and head end of the lower cylinder are similar, the admission valves being located in the valve boxes, which are bolted to the cylinder heads. There are no exhaust valves required, the products of combustion escaping through slots in the middle of the cylinder from which the exhaust pipe leads. These slots are covered by the long motor piston.

The combustion mixture is admitted through two double-acting pumps, the one for gas, the other for air. The crank ends of the air pump and gas pump discharge into the crank end of the power cylinder, and the head ends of the pumps discharge into the head end of the power cylinder. The gas and air are compressed to about 9 pounds per square inch by the pumps.

The combustible mixture of gas and air is produced only at the inlet of the cylinder. There is no storing of it. The mingling of the air first introduced with the burnt residue gases, or with the succeeding charge of combustible mixture, is avoided by the construction of the admission device. For the same reason there is no loss of mixture through the exhaust ports.

The pump is provided with piston valves, with the valve gear so arranged that its maximum capacity cannot exceed 50 or 60 per cent. of its total displacement. For after the pump has completed the suction stroke, the gas suction port is left open during a portion of the succeeding (compression) stroke, so that the gas can return without increase in pressure until the suction port is closed, when the gas is compressed and passed out through the compression port. The

amount of gas thus furnished corresponds to the maximum power of the engine.

The engine is started with compressed air. Engines to which blowing cylinders are attached are easily started with air under 150 pounds pressure. For those without such cylinders 90 to 120 pounds pressure is sufficient. These engines are built in sizes ranging from 400 to 2,000 horse-power.—*Engineering and Mining Journal.*

Compressed Air or Steam Hammer.

The American Engineering Works of Chicago, are building post hammers which are particularly well adapted for railroad, mining, blacksmith and general machine shops. They are designed to be driven either by steam or by air. A special valve movement and treadle for handling these hammers has been patented. It is so arranged that a slight movement of the treadle causes the ram to rise to top of its stroke and remain there for any length of time desired, thus enabling the operator to adjust work or tools on the lower die. If the treadle is then pressed down to the limit the ram will give a hard, full blow, the same as a drop hammer; or the treadle can be pressed down part way, when the hammer will give repeated hard or light blows, as may be required. This special valve gear permits one man to easily handle the hammer for drawing or regular forge work, or for die work. The change from one kind of blow to the other is made instantly and smoothly.

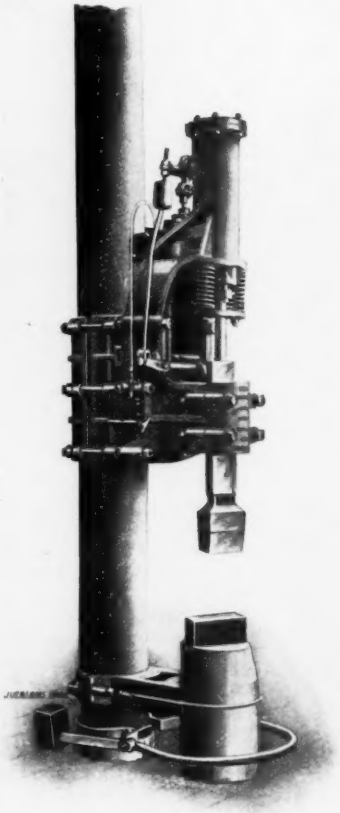
The cylinder and frame are cast in one piece from best quality, close grained gray iron. The exhaust ports are so arranged as to keep the cylinders always drained. The piston is forged solid with the piston rod from the best quality of O. H. steel.

The ram is a steel forging square in form where it passes through the lower part of the frame which acts as a guide. The lower end of the ram is aranged to receive the upper die in such a position that it stands at an angle of 45 degrees to the post supporting the hammer, thus enabling long pieces to be worked either way of the die without coming in contact with the post.

The upper and lower dies are steel forgings fastened by means of dovetail and wedges so that they can be easily removed.

The anvil is designed to be secured to a wooden block set on end, the anvil being bolted to the block with lag screws.

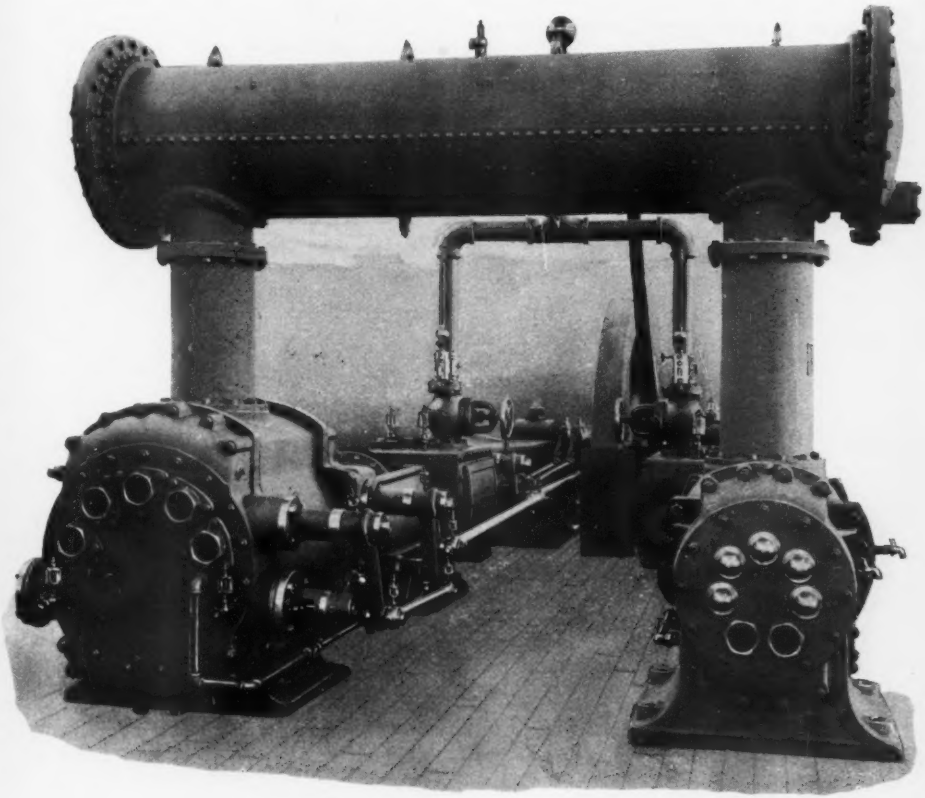
The weight of the falling parts (the piston, piston rod, ram and die) designates the size of the hammer.



The hammer is usually arranged for bolting to a wooden post. Special attachments will be furnished when so ordered for bolting to a wrought steel column, or where preferred a steel column made of extra heavy wrought pipe will be furnished, together with the necessary clamps for properly clamping frame of the hammer.

Compressors at the Canadian Niagara Falls Power Co.

The entire work of the excavating plant at the above company's works is being accomplished by rock drills run by compressed air, which power is supplied by two large steam driven compressors, built and installed by the Canadian Rand Drill Co. We show herewith a picture of one



of the compressors. These machines are of the duplex steam, cross compound air type, and indicate 300 h. p. each. Entering a conduit leading from the open air to the compressor, the air is admitted at atmospheric pressure to the low pressure air cylinder through Corliss valves, actuated from the main shaft by eccentrics. Here it is compressed to 30 lbs. per square inch, the temperature of the air being kept as low as possible by means of the circulating water with which the water jacket surrounding the cylinder is kept filled. The air is then discharged into the intercooler, which is of the Rand water tube type, so well and favorably known to the Canadian engineering world on account of the excellent results that have been obtained from machines installed by this firm in British Columbia, Cape Breton and other parts of Canada. This intercooler practically consists of a large cylinder, made of steel plate, and filled with pipes in which cold water in circulated. An ar-

rangement of internal plates forces the air to pass transversely across the pipes, thus removing a large proportion of the heat of compression. After passing through the intercooler, the air enters the high pressure cylinder, and is there compressed to 100 lbs. per square inch. The compressors discharge the air into the air receiver, which takes up the air pulsations, thereby equalizing the pressure. From the air receiver the air passes into the pipe line, from which it is taken off by the different machines. The general dimensions of the compressors are: Steam cylinders, 18 inches in diameter; high pressure air cylinder, 18 inches in diameter; low pressure air cylinder, 28 inches in diameter; stroke, 24 inches. The compressors run at a speed of 100 revolutions per minute, and each machine has a capacity of 1,700 cubic feet of free air per minute.

Mail Tubes for Chicago.

Contracts for about nine miles of pneumatic tube service in Chicago, taking in a number of the depots and postal stations, were let Jan. 24, by the postoffice authorities at Washington, to the Chicago Pneumatic Tube Co. An annual rental of $13,750 per mile is paid by the government. At least three miles of the pneumatic tubes must be in operation within a year, and the entire system contracted for must be completed within three years. The tubes will center in the new postoffice building, and if the three miles to be completed within a year are to be used in the service the temporary postoffice will either be abandoned within that time for the new site, or connections will be made with the structure on the lake front. Three separate tube lines are provided for in the contract. The longest one is to cover the principal South Side stations. It will start from Adams and Dearborn and run east in Adams street to the lake front, where a turn south is to be made, the tubes continuing through the park to the Twelfth street station of the Illinois Central R. R. A new postal station will be established at Twelfth street to handle local business in addition to the railway mail service. From Twelfth street the tubes will run south in Indiana avenue to Twenty-second street, where the Twenty-second street postal station is located. They will continue south to Thirty-second street, where the Armour station is situated, and further south to the stock yards station. Forty-second and Halsted streets, which is the terminus of the south tube system. The west tube system will run from the new Federal building west to the board of trade postal station in the Rand-McNally building, and from there west to the Union depot. This line will handle railway mail as well as the business of the Union depot postal station. The north system will run beside the south system to the Lake Front park, thence north to the temporarry postoffice, or to a new postal station to be established nearby when the temporary postoffice is abandoned. The tubes will extend to the South Water station at 15 La Salle street and under the river to the Northwestern depot, which will be the terminus. A new postal station will be established either inside of or near the depot. All the tubes will be 8 ins. diameter, inside measurement, and of uniformity, so that the carriers can be interchanged. It is left to the successful bidders to make arrangements with the city for the use of the streets which the tubes will traverse.—*Railway and Engineering Review.*

Tunnel Construction for the Cables of the Illinois Telephone & Telegraph Co.

Quite in contrast with much of the work connected with the subway construction in New York City, is the building of the tunnels in Chicago for the cables of the Illinois Telephone & Telegraph Co. This work has been carried on so quietly, with practically no plant on the surface to attract unusual attention, that very few of the people that frequented the busy thoroughfares of the business district of Chicago were aware of, the magnitude of the work until some 12 miles of tunnels had been completed. It is really remarkable that a work of this magnitude should have been constructed without a single complaint from a taxpayer or a pedestrian on the streets, or a complaint from any department of the City Hall. The Department of Public Works in the city of

Chicago, during the construction of the 12 miles of conduit, saw that the work was done in such a manner that there would be no possible chance of any unfavorable criticism from taxpayers, they keeping almost hourly reports of the work as it progressed. *Mines and Minerals* in their January issue describes the sinking of the shafts as follows:

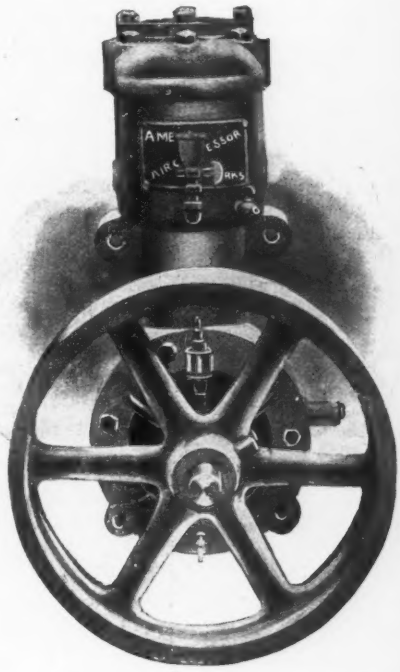
"A steel caisson was used, made of No. 12 steel plate with a 3-inch angle iron riveted to the plate at the top and bottom. These steel plates were made in sections 18 inches deep, and divided in proper lengths to fit a semicircle 9 feet in diameter. The sections of steel plates and lagging were bolted together as the excavation was being done, or, in other words, the depth of the section being 18 inches, only about 18 inches at a time were excavated in depth, and as the individual plate sections were about 5 feet long, pockets about 18 inches deep, 2 feet wide, and 6 feet long were excavated, which excavation allowed the placing of one of the sections to a completed upper section. By this method of closely following the excavation with the plate lining, any chance of settlement in the ground or caving in was obviated. After the shafts had been sunk to the proper depth, a 7-inch wall of concrete was constructed inside of the caisson.

"After satisfying themselves as to the nature of the subsoil, the company settled upon the method for carrying out the work, and the pneumatic system was adopted, as experience dictated that it was the most economical and safest. While it was not altogether necessary to use this system, as the nature of the soil gone through was such that it would stand without caving or swelling, the pneumatic system was introduced more for the purpose of protection in case it was necessary that the work should be left for a time in an uncompleted state. In installing the pneumatic system, air locks were placed just outside the several shafts."

A small Vertical Belt Air Compressor.

This compressor is manufactured by the American Air Compressor Works and is built in three sizes, namely, No. 4, No. 6 and No. 7, having a capacity of 6, 16 and 25 cubic feet per minute, and suitable for any pressure up to 100 lbs. per square inch.

These machines work on the double acting or compound principle, that is they partially compress the air on the down



A SMALL VERTICAL BELT AIR COMPRESSOR.

stroke, then passes on into the other side of piston where it is again compressed to the pressure desired.

These machines are built with improved metallic (Poppet valves), water jackets around air cylinder, fly wheel pulley, lubricator, oil cups, and all other mountings complete. The machines are particularly adapted for experimental and laboratory work, No. 7 size being used quite extensively for operating three stone hammers. They are also adaptable for operating moulding machines and air hoists.

Notes.

At a meeting of the Board of Directors of the Allis-Chalmers Company held January 15th, 1903, regular quarterly dividend was declared on preferred stock.

Steel cars are being cleaned by the Pittsburg & Lake Erie with compressed air, and the Pennsylvania is giving the subject attention with a view to improving methods it has employed.

The generating plant of the Northern California Power Company at Cow Creek in the high Sierras, furnishes current from that and another station for ore smelting, for operating air compressors, for town lighting, for water works and for the irrigation of land.

The Empire Engine and Hoist Co. report that they have just completed the filling of an order for 24 Empire air drills to the U. S. Navy Yard, at Brooklyn, N. Y., at which place they have had in operation for the past few years not only many other Empire air drills, but numerous Empire air hoists as well.

Mr. A. C. Amos, of 20 Bucklersbury, London, E. C., announces that he has been appointed sole London agent to the Consolidated Pneumatic Tool Company, Limited, which is an amalgamation of the New Taite Howard Pneumatic Tool Company, Limited, and the International Pneumatic Tool Company, Limited.

It is reported that the British Schuckert Electric Co., Ltd., Surrey Street, London, W. C., have sent out a blue print showing the results of rock drilling tests at the Düsseldorf Exhibition. This indicates that the combined Meyer-Schuckert electrically-driven compressed air percussion drill achieved results nearly 33 per cent. better than the second best competitor.

The International Correspondence Schools of Scranton, Pa., have issued a little booklet called "One Thousand and One Stories of Success," which they intend sending to all prospective students. This publication proves beyond a doubt the genuineness of the International School's prosperity, and we especially wish to congratulate them on the well gotten up little booklet.

In the machine shops of the Hydraulic Installation at the Panuco Mines in Mexico, many pneumatic tools are in use; the steam hammers in the smiths' shops are run by compressed air in place of steam; the largest hoisting plant is run direct by a water-power motor, and the general existing circumstances seem to point in favor of compressed air being used for general underground purposes; and this, after the fullest consideration, has been finally adopted, and the general results obtained after its installation fully justify its adoption.

Ottoffy & Williams of St. Louis, Mo., sent a communication to Jacksonville, Fla., calling attention to their new invention, consisting of a van for the purpose of washing and sprinkling streets by means of compressed air. The street board considered it wise to investigate this device and get further data and information in regard to the subject, and Superintendent of Streets, S. L. Earle, will communicate with the inventors and manufacturers and report as soon as he has definite information. There have been numerous complaints regarding the bad condition of the streets.

The directors of the American Pneumatic Service Company, in a circular letter to stockholders, outline the work of the company, the development of the pneumatic tube system, the plans for the extension of the business of the company, the needs of the company for ready cash, and say:

"For these reasons your directors have unanimously voted to defer action upon the payment of any dividend on the preferred stock for the present, and they are advised that by so doing the rights of the preferred stockholders to share in dividends out of the past year, as well as out of earnings during the period in which earnings are thus employed, are preserved and protected."

An estimate of $10,000 has been transmitted to the House at Washington, D. C.,

to pay the annual rental of a pneumatic tube service proposed to be established in the treasury building. The letter of transmittal contains a statement from Supervising Architect Taylor, which states that under the direction of the Secretary various proposals have been received for a pneumatic tube service in the treasury building, and also between that building and the various executive buildings, said proposals being much in detail, one of which is for the rental of a pneumatic tube service in the treasury building, the department to furnish the power therefor, for which rental and expenses incident thereto an annual expense of $10,000 will be involved.

Within the last month, before the Birmingham Students' Engineering and Metallurgical Society, England, Mr. A. Craven read a paper on "Pneumatic Tools, their Construction and Uses." The author having briefly indicated the great expansion in the use of these tools in British works, described very fully the construction of the chief types of those in general use, and also of some of their prototypes. In this description he included chipping and caulking tools, drills, hoists, hammers, rivetters, etc., and afterwards showed by means of lantern slides, the many and varied uses to which these may be adapted, and compared the work done with them to hand work, actual examples of such work being shown for comparison.

The efficiency of compressed air plants can be greatly increased by reheating. The gains are both direct and indirect. The chief direct gain is in the greatly increased efficiency of fuel used in the heating stoves as compared with the effect when coal is burned under boilers. It is commonly stated, and the statement is fairly correct, that when one pound of coal is burned in a reheater stove the commercial effect is as great as when three pounds are burned under a boiler. The increase in commercial efficiency when reheating air from 60° to 400° F. may be put at 35 per cent. The indirect gains are: 1. Better lubrication of the compressed air engine. 2. Less investment required as a smaller plant will be required. 3. Reduction of compressor engine friction as compared with the useful work done. In the next few years we hope to see all mines using compressed air have reheater stoves.

It seems rather pathetic nowadays when a leading railroad reports that the air brakes on a fast freight train must wait for test until the locomotive is backed down from the shops and coupled to the train, and when a full hour is consumed in the testing. Yet this is the situation on some of the railroads which otherwise have a claim to greatness. The time of testing will be largely reduced if the yards are equipped with testing plants where an important train may be tested while it is being made up, or immediately after, thus doing away with the necessity of waiting for the engine and consuming valuable time after the crews have been called and are ready to start.

This old-time method, which should be immediately regulated as exceedingly costly and behind the times, should be replaced by a more modern one of yard testing plant, which will greatly facilitate the air-brake service.

The physiological effects of working in compressed air have been studied during the placing of foundations for a lock in the Danube at Vienna. The work required nearly three years, and in this time 675 men were employed for an average of 553 hours under pressures of one to five atmospheres above the normal. Each working shift of four hours was followed by eight hours off duty. Included in the working time were the rests in the air-locks to become gradually accustomed to the pressure changes, from 5 to 35 minutes being necessary on entering and a longer period up to 20 minutes for each atmosphere on leaving. The results have led to the conclusion that carefully-selected men may work under pressures up to 75 pounds to the square inch without serious risk. Yet of these men nearly one-half were obliged to go to the hospital, two dying and six being permanently injured, and it was found that sufferers from nasal catarrh, ear troubles or bad digestion were specially unfit for employment.

When using the term motor, one should not always have in mind an electric motor,

as we believe that a great deal of the economy which has been arrived at by the use of individual electric motors can be very closely approximated by the use of individual steam or compressed air motors. There are quite a number of small steam motors which are quite efficient, and it is very noticeable in factories abroad how the use of small steam engines driving different parts of factories, instead of their being coupled to one main engine, has been adopted. In Paris the use of individual air motors is a very common practice, and in Germany the use of individual gas engines is nearly as well developed.

Recent developments in the direct compression of air by falling water, from which a very much larger net effect can be obtained by means of preheating and premoistening before using in motors, and the possibilities of distributing perfectly dry, cold compressed air long distances without serious losses will in the near future bring the use of individual air-driven motors into greater prominence.

The Morning Mining & Milling Co., Idaho, employs in exploitation a well planned power system, most of which is used for making compressed air. The water is gathered from various streams high up on the mountains above the compressor site, and conveyed to the wheels by three pipe lines of 1400, 1200 and 140 feet head, respectively. The 1400 and 1200-foot heads are delivered by separate nozzles on a Pelton wheel 32½ feet in diameter. The 140-foot head is used to drive two 11-foot Pelton wheels, one on each side of the big one and on the same shaft. There are two compressors, one on each end of the water wheel shaft. They have 18 x 32½ x 42-inch cylinders, with intercoolers. The air is compressed to 28 pounds in the low-pressure cylinder, and delivered by the high-pressure cylinder at 90 pounds. Running at full speed these machines compress about 6000 cubic feet of free air per minute. The pipes which convey this air to the mine cost more than the machinery. They comprise 9200 feet of 12½-inch pipe to No. 6 tunnel, at which point the air is divided into two lines of 9-inch pipe, one entering No. 6 tunnel, which will be 2 miles long, and another leading 4½ miles to No. 5 tunnel.

The beneficient results of keeping electrical or other particularly vulnerable machines clean are very generally realized, but the flexibility and efficacy of compressed air as a cleaner of such machines are not appreciated as universally as they might be, judging from the relatively limited number of such applications. One, and possibly the chief advantage derivable from the use of compressed air to clean dynamos, motors, etc., is the ability to remove collections of foreign material without touching the parts of a machine on which they are lodged. By no other means is it possible to remove oil-soaked copper or carbon dust, for example, without either wiping or scraping the coated part. Perfect cleaning by wiping is almost impossible, to say nothing of the liability of making matters worse by the use of dirty waste or pieces of cloth; the serious objection to the scraping process is obvious. Another advantage of a compressed air cleaning system is that an outlet may be (and usually is) provided near each piece of machinery or apparatus, so that in many cases each one can be at least partially cleaned while in operation. In the worst cases, except those of enclosed machines, a shut-down of only very short duration is necessary for effecting complete cleaning.

The Krupp Colleries of Essen, Rhenish Prussia, are three in number, namely Hannover, Hannibal and Sälzer and Neuack, all in Westphalia. These have seven working-shafts altogether, furnishing the entire coal supply of the Essen Works and also the greater part of the coal and coke supply for the remaining Krupp Works.

The plant at the Hannover and Hannibal United Collieries comprises seven shafts, of which five are winding shafts. Another winding shaft is being constructed. The greatest depth is 550 yards. The various plants work 30 seams with a total thickness of 111 ft. The "Hannover" and "Hannibal United" Collieries have, among other machinery, three surface and six underground pumping engines with a total delivery per minute of 529 cubic feet of water to an average height of 448 yards; six hydraulic air compressors which take in per hour 353,000 cubic feet of air at atmospheric pressure for the working of underground compressed air engines;

three fans (and one spare ventilator) acting by suction with a total delivery per minute of 350,000 cubic feet; and four coal-separation and three washing plants with an output of 200 tons per hour.

The total output in 1901 of the Krupp mines amounted to 1,479,334 metrical tons of coal.

The ordinary gasoline blow torch commonly used in paint shops for removing old paint from cars and trucks preparatory to repainting, says the *Automobile Review*, is not only an inconvenient thing to handle, but is constantly a menace to property and requires the strictest attention to prevent fires.

Mr. J. Millar, superintendent of rolling stock for the International Ry., of Buffalo, has abandoned the use of blow torches entirely in this work and now uses a home-made sand blast consisting of a sand tank, a few feet of ¾-inch iron pipe, and a nozzle made by flattening out a piece of ¾-inch iron pipe. Compressed air is taken through the iron pipe from an air compressor in the main shops. The sand which must be of fine clean quality is fed from the tank into the air pipe in the manner indicated in the diagram, the force of air combined with gravity, being sufficient to draw the sand down into the pipe in a good steady stream. By means of the flexible connection and nozzle one man directs the sand against the surface to be cleaned, exactly in the same way as he would handle a blow torch of any kind. Mr. Millar states that with an air pressure of approximately 90 lbs. and a good quality of sand every particle of old paint is removed and a cleaner surface is secured than could be obtained with a blow-pipe flame, and in just one-half the time, inasmuch as one man now does the work formerly requiring the services of two men.

Electricity is not being largely adopted in Australian mining so far; the real reason for this does not arise from want of appreciation of the advantages as much as from the difficulty of obtaining immediate deliveries. German and American motors are in places obtainable, but there is absolutely no chance of obtaining British plant subject to any reasonable date of delivery. In large mines, like the Broken Hill Proprietory, where the tonnage is large, 10,000 tons per week, electric haulage has been adopted, and all trucking is done by electric motors instead of horses at considerable reduction in cost. In most large mines throughout the colonies also the lighting is electric, but electric winding engines and drills are not in use. Even at the Kolar mines, India, where water power is available and there is an electric supply, the hoists and drills are worked by compressed air. Apart from the advantages as regards ventilation by the use of compressed air, compressors can be very cheaply run where electric power is available, as the motor and compressor can be run always at high efficiency. Receiver capacity of sufficient volume can always be provided, and by reheating the air both drills and hoist can be run continuously, as the compressor will recharge the receiver between the skips, the demand of the drills being comparatively light. The fuel required for 150 horse-power for reheating will only average about a cord a day, and the hoisting charges, where electric power costs, say, £10 per horse power per annum, would not, for ordinary depths, amount to more than 1s. per ton milled.

We take the liberty of reprinting a note found in the *Daily News*, London, reading as follows:

"Compressed air (writes an enthusiastic correspondent) is one of the few natural forces which has not as yet received its due share of attention in the Press. It has, however, a journal of its own, published in America, and printed in the most luxurious style. Many of us scarcely realize the importance of compressed air. It may therefore be described as the inspiration of a football or a Dunlop tire. It is, moreover, compressed air which breathes manifold music from the souls of organs, and which lends rotundity to the cheeks of Sousa's performance on the trombone.

"It is compressed air (he continues) which causes lovers to sigh and steam whistles to shriek. It boos from the foghorn and catcalls through the siren. And recently it was to be found opposite the

National Liberal Club, where it was being carried about in a kind of red vehicle—a cross between a motor-car and a water-cart.

"A pipe led from it through the windows of a hotel, where something must have been going on inside. But what? Were people having a little ozone in the drawing room? I rather suspect that the furniture was being cleaned by means of the syringe, through which the air is directed whenever there is dust. It is far more efficacious than brushing or beating the poor armchairs, and compressed air is frequently used to cleanse railway carriages. It is the regular agency for stamping glass mugs. Air mixed with sand is driven through a stencil, and eats its way into the vessel in a very few minutes—as may be seen at any London County Council laboratory for testing such measures.

A more or less new shaft sinking system has been recently introduced by Mr. Charles Walker, of Doncaster, England, and two 24 ft. 6 in. pits are now being sunk with it by him at the Sherwood Collieries, Mansfield, Notts., with great success. The power adopted has been compressed air, combined with hand-boring, and the whole of the plant has been manufactured by the Hardy Patent Pick Co., Ltd., Sheffield. The sinking frame proper consists of an iron or steel ring, in this case 8 ft. in diameter, with a tee-slot annular groove. Upon this ring are mounted eight arms, each telescopic, and provided with jack screws, the end-mounting on the ring being secured by suitable clamps, held down by tee-bolts in the annular slot. The frame is also provided with telescopic legs, which adjust themselves to any irregularity in the pit bottom, and on the telescopic arms the boring machines are mounted in any desired position. The circumference of the frame is indexed with figures showing the position the arms must be in to drill any desired number of holes. For example, let us suppose that it is desired to drill a round of 16 side holes. Each of the eight arms must be over the arrow marked 16. These holes are then put down the desired depth, and one moving of each arm to the next arrow marked 16 completes the round. Following on these, 14 sumpers may be required. The machines must be worked back on the arms to the mark thereon for the proper diameter of the ring for sumpers, and the drilling in each case commenced and finished over the arrow marked 14, and so on; so that it will be readily seen that there is no loss of time in marking out, but the mathematical accuracy of the drilling enables the chargeman to reap the full advantage of his firing.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz.: all communications should be written on one side of the paper only; they should be short and to the point.

COMPRESSED AIR:

Gentlemen—We note in your issue of December, Volume 7, No. 10, you show on page 2104, a pneumatic sand rammer, and we should like to know from whom we can get prices and other information in regard to one of these complete, which you specify as weighing about 20 lbs.

We would like to have the information promptly, and would consider it a favor if you would favor us with an early reply.

Yours truly,
WESTERN TUBE COMPANY.

WESTERN TUBE CO.,
Kewanee, Ills.

Gentlemen:

We find on looking into the matter that the Pneumatic Rammer, shown on page 2104, of the December number, is manufactured by the Philadelphia Pneumatic Tool Co., 1038 Ridge Ave., Philadelphia, Pa., and we believe they publish a special pamphlet describing this rammer and suggest that you write to them. We are sending a copy of your letter to this Company and trust that you will approve of our action.

Yours very truly,
COMPRESSED AIR.

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U. S. PATENTS GRANTED DEC. 1902

Specially prepared for COMPRESSED AIR.

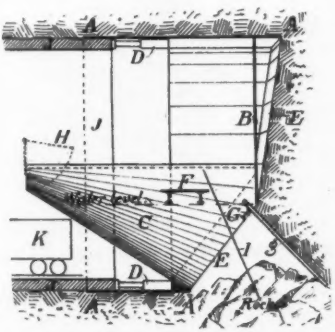
714,662. DOOR FOR HOUSING OF PNEUMATIC ELEVATORS. Chester Bradford, Indianapolis, Ind. Filed May 17, 1902. Serial No. 107,797.

The combination, in a boot or housing for pneumatic elevators having an opening in the bottom thereof, of a door for closing said opening consisting of a piece adapted to fit therein, a frame carrying said piece formed at one end to engage with a supporting device carried by the sides of the housing and having ears at the other end, locking-bolts engaging with said ears, and the housing sides provided with lugs with which said locking-bolts may also engage.

714,873. PNEUMATIC CARRIER SYSTEM. Wilbur G. Davis, Newton, Mass. Filed Dec. 2, 1901. Serial No. 84,297.

A pneumatic-carrier system comprising a carrier, a normally dead transmitting-tube therefor, a reservoir containing air at a pressure at variance with the pressure in said tube, means to place said reservoir in communication with the end of said tube, to cause the difference in pressure between the air in said reservoir and that in said tube to establish propelling movement of air through said tube, a closure for the opposite end of said tube and automatic means for holding said closure withdrawn from the end of said tube during flight of a carrier toward it through said tube.

715,244. PNEUMATIC TUNNELING SHIELD. Theodore Cooper, New York, N. Y. Filed May 31, 1902. Serial No. 109,648.



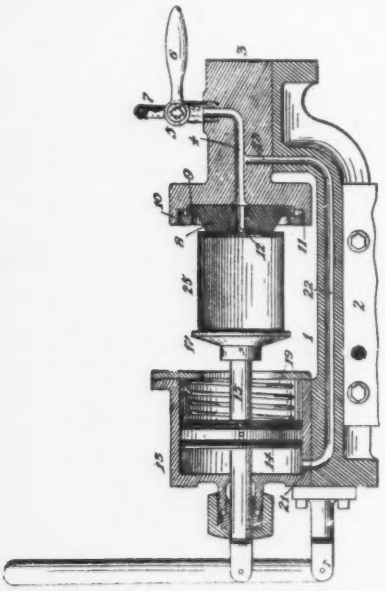
The combination with a tunneling-shield of an after bulkhead therein comprising a conically-shaped trough having its axis parallel with the axis of the shield and extending rearwardly from the cutting edge of the shield at or near which its forward edges attach.

714,874. PRESSURE-CREATING DEVICE FOR CASH CARRIER SYSTEMS. Wilbur G. Davis, Newton, Mass. Filed Dec. 9, 1901. Serial No. 85,144.

A pneumatic propelling device comprising a segmental inclosing case having one or more flat faces, a rotary reciprocatory member in said case and treadle means for reciprocating it, inlet and outlet openings in said flat face at each side of the axis of said reciprocatory member, valves for said openings and means to support said case in position with its said flat face or faces and said inlet-openings uppermost.

715,324. CAN-TESTING MACHINE. Newton B. Wachhorst and Maurice J. Ross, San Francisco, Cal. Filed September 4, 1902. Serial No. 122,104.

In a can-testing machine, a can-clamp, means for admitting air to the can while in

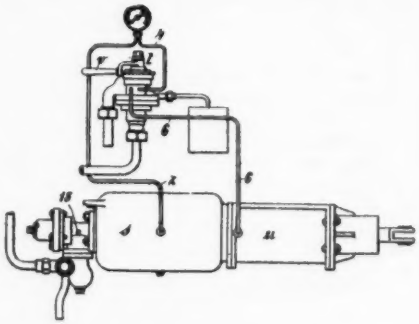


the clamp, means for pneumatically maintaining the clamp, and means for releasing the clamp at a break in the air-pressure.

715,349. PNEUMATIC STRAW-STACKER FOR THRESHING MACHINES. Robert Christie and Thomas B. Christie, Hamilton, Canada. Filed June 9, 1902. Serial No. 110,712.

715,585. COMPRESSED-AIR BRAKE F. RAILWAYS. Leon Kirchner, Mulhouse, Germany, assignor of one-half to Johannes Handschen, Basle, Switzerland. Filed Oct. 7, 1902. Serial No. 126,307.

In compressed air-brakes for railways, the combination with an auxiliary air-reservoir and its brake-cylinder of a differential elastic-tube manometer permanently connected by one



of its elastic tubes with the said auxiliary air-reservoir and means controlled by the brake-operating valve for connecting the other manometer-tube to the brake-cylinder on an ordinary service braking so as to indicate then the difference or equality of pressure both in the auxiliary air-reservoir and in the brake-cylinder.

715,723. PNEUMATIC SPRING FOR VEHICLES. William C. Wood, Wetumpka, Ala. Filed April 19, 1902. Serial No. 103,832.

715,760. PNEUMATIC STACKER FOR STALK-SHREDDING MACHINES. Charles E. Curtiss, Chicago, Ill., assignor to International Harvester Company, Chicago, Ill., a Corporation of New Jersey. Filed June 28, 1902. Serial No. 113,602.

715,800. AIR AND GAS MIXER. Charles W. Hinman, Boston, Mass. Filed April 15, 1902. Serial No. 103,018.

In a gas-lighting and heating apparatus, a holder for holding a variable volume of mixed air and gas under constant pressure, a delivery pipe leading from it to the burner, a pump connected with said holder for simultaneously delivering measured volumes of air and gas thereto, air and gas inlets to said pump, means controlled by the volume of

mixed air and gas in said holder for regulating the delivery of air and gas thereto, and a motor for operating said pump.

716,031. PNEUMATIC TIRE. Henry N. B. Good, London, England. Filed Mar. 17, 1902. Serial No. 98,574.

716,196. COMBINED AIR-BRAKE AND SLACK-ADJUSTING MECHANISM. James M. Craig and William H. Buck, Denver, Colo. Filed Feb. 27, 1902. Serial No. 95,932.

The combination with brake devices, of a cylinder, two pistons therein, means for introducing air to the cylinder between the pistons, stems connected with the pistons and protruding from the opposite extremities of the cylinder, levers connected with the protruding piston-stems and suitably fulcrumed, a stationary frame suitably mounted, ratchet-bars slidable in the frame, dogs mounted in the frame and engaging said bars, and a suitable connection between the ratchet-bars and the piston-stem levers, and between the said levers and the brake-levers of the car-trucks, for taking up slack in the brake-rigging, substantially as described.

716,212. PNEUMATIC-DESPATCH-TUBE-SYSTEM. Edmond A. Fordyce, Chicago, Ill. Filed Aug. 4, 1902. Serial No. 118,-267.

In a pneumatic-despatch-tube system, the combination with a trunk-tube and a blower connected therewith, of a series of pairs of tubes tapping said trunk-tube and leading respectively to outlying stations, and cut-out valves interposed in said trunk-tube between the individual tubes of each pair of the series, respectively, substantially as described.

716,213. CARRIER FOR PNEUMATIC-DESPATCH TUBES. Edmund A. Fordyce, Chicago, Ill. Filed Aug. 4, 1902. Serial No. 118,268.

716,251. PNEUMATIC HAT-BLOCK. Robert Lamont and Charles E. Weatherhead, Denver, Colo. Filed June 3, 1902. Serial No. 110,104.

As an improved article of manufacture, a pneumatic hat-block comprising a base, an inflatable portion attached to the base, and a flexible air-escape conduit extending through the block, substantially as described and for the purpose set forth.

716,323. PNEUMATIC SIPHON. Andrew J. Weekley, East Pittsburg, Pa. Filed April 4, 1902. Serial No. 101,379.

In a pneumatic siphon, the combination of a body portion, an air-inlet, a refuse-inlet and a common outlet formed therein, said body portion being provided with an inclined side between said refuse-inlet and said outlet-port, and means provided in said air-inlet for deflecting the injected air against said inclined side, substantially as described.

716,498. SUBBASS FOR SELF-PLAYING ORGANS. Charles Warren, Guelph, Canada, assignor to the Bell Organ and Piano Company, Limited, Guelph, Ontario, Canada, a Corporation. Filed May 10, 1901. Serial No. 59,675.

In pneumatic-organs, the combination with the upper and lower vacuum-chambers, diaphragms, tubes and tracker-board and pneumatics coacting with same, of a subbass-chamber having a mute opening and pneumatics located therein beneath the top of the same, tubes connecting such pneumatics with the passage-ways leading to the upper portion of the vacuum-chamber, the reed-box and reeds located in chambers therein, such reeds extending downwardly through the main or lower vacuum-chamber into the exhaust-bellows and the pallets extending over the top of the reed-box chambers and connections between the pallets and pneumatics as specified.

716,499. MOTOR FOR SELF-PLAYING ORGANS. Charles Warren, Guelph, Canada, assignor to the Bell Organ and Piano Company, Limited, Guelph, Ontario, Canada. Filed Oct. 11, 1901. Serial No. 78,324.

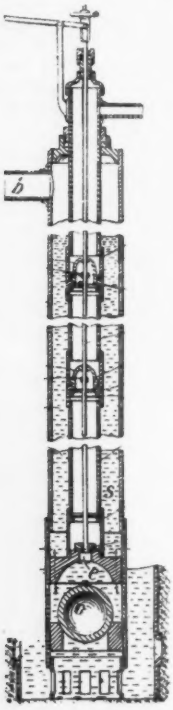
In a pneumatic organ, the combination with the motor and spindle thereof and the music-sheet and driving-drum therefor, and gear-wheel on the spindle of the driving-drum, of the supplemental spindle provided with a gear-pinion at one end meshing with the gear-wheel on the driving-drum, a sleeve secured on the opposite end provided with longitudinal slots extending lengthwise over the end of the motor-spindle, and a pin extending through the motor-spindle and the slots whereby the supplemental spindle may be moved longitudinally to throw the pinion in and out of gear without disturbing the operative relation between the two spindles, as specified.

716,693. PNEUMATIC INNER TUBE FOR TIRES. Charles E. A. Esse, Ormskirk, England, assignor of one-half to James Hamilton Cobley, London England. Filed May 16, 1902. Serial No. 107,670.

716,783. PNEUMATICALLY-ACTUATED CAR DOOR. Albert W. Sullivan and William Renshaw, Chicago, Ill. Filed April 13, 1901. Serial No. 55,638.

In combination with a sliding door, means for actuating the same including an abutment on the door, a reciprocatory member, a collet carried by said member and adapted to contact with the abutment on the door, a guide supported by the framework of the door and engaging said collet, and means for shifting the reciprocatory member, substantially as described.

716,839. AIR OR STEAM OPERATED PUMP. Franklin Heil, Santa Ana, Cal. Filed Feb. 20, 1901. Serial No. 48,176.

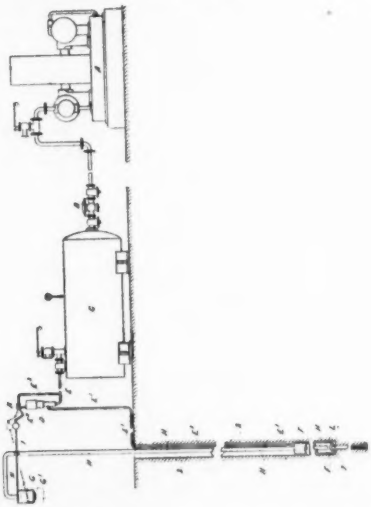


A pump comprising a lifting-pipe; a check-valve at the lower end thereof; an air or steam pipe furnished at its lower end with an outlet directly above the check-valve; a valve for said outlet; means for supplying air or steam under pressure to the air or steam pipe; and means for periodically operating the valve for the outlet of said air or steam pipe.

717,046. SOUNDING MECHANISM FOR TELEGRAPH-OFFICES. John C. Stewart, U. S. Army, assignor of one-half to Andrew S. Burt, U. S. Army. Filed March 18, 1902. Serial No. 98,807.

The combination with a relay-magnet and a sounder of a telegraph-station plant, of a pneumatically-operated motor mechanism for the sounder, a valve for controlling said pneumatically-operated motor mechanism and an armature for the relay-magnet supported directly by said valve; substantially as described.

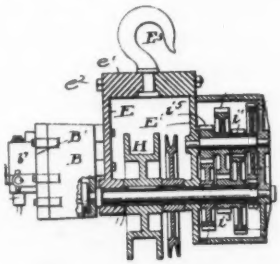
717,048. APPARATUS FOR RAISING LIQUIDS SUCH AS OIL, FROM OIL-WELLS BY DIRECT AIR-PRESSURE. Robert Stirling, Baku, Russia. Filed July 10, 1902. Serial No. 115,096.



An apparatus for raising liquid from deep wells by air-pressure, the combination of a closed chamber located in the well and fitted with a non-return inlet-valve for the admis-

sion thereinto of the liquid to be raised, a pipe for discharging said liquid out of said chamber, an air-pipe connected to said chamber, a piston-valve having a smaller end piston normally exposed to the compressed air and an opposite larger end piston, a three-way valve opening communication between said larger piston and the atmosphere to permit said valve to be opened and a supply of compressed air to be conducted through said air-pipe to said chamber to expel and raise the liquid therefrom and alternately opening communication between said larger piston and the compressed-air supply to move said valve to cut off the supply of compressed air to said chamber, and an automatic device exterior to said chamber and operated by the discharge therefrom for alternately opening and closing said three-way valve.

717,243. HOIST. Edward Y. Moore, Cleveland, Ohio, assignor, by mesne assignments, to Chicago Pneumatic Tool Company, a Corporation of New Jersey. Filed May 15, 1901. Serial No. 60,322.



In a hoist, the combination of a pneumatic motor, a direct-acting elevating-drum, straight-line reduction-gearing connecting said drum to said motor, and a governing-valve for said motor adapted on one position to positively entrap the air in the engine whereby the air alone blocks the pistons and sustains the load on the straight-line reduction-gearing, substantially as described.

717,264. PNEUMATIC TIRE. Herbert R. Palmer, Cleveland, Ohio, assignor of one-half to Omar Stoppel, Cleveland, Ohio. Filed Oct. 11, 1902. Serial No. 126,862.

717,312. PNEUMATIC STACKER. Edward P. Alsted, Truesdell, Wis. Filed May 8, 1902. Serial No. 106,379.

717,465. PNEUMATIC STACKER. Albert A. Stelting, Madison, Wis. Filed Aug. 6, 1902. Serial No. 118,675.

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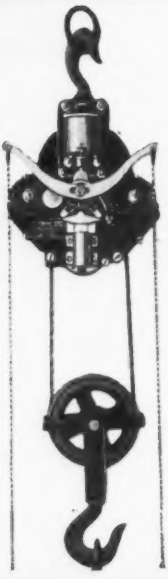

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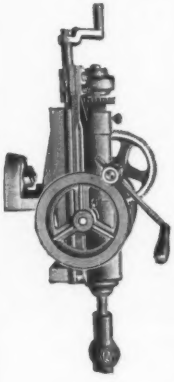

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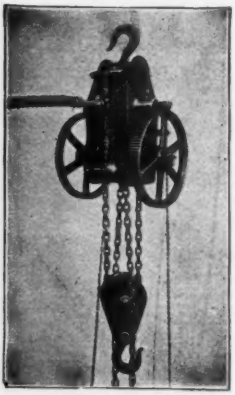

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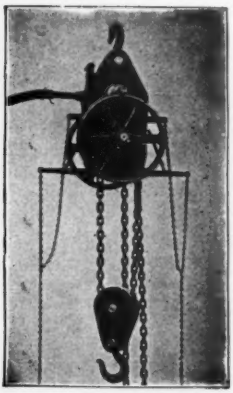

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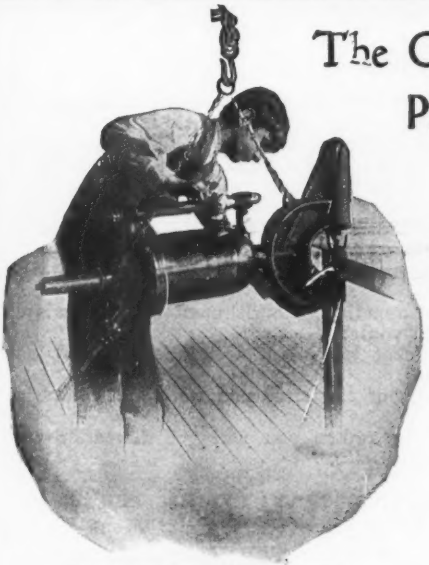

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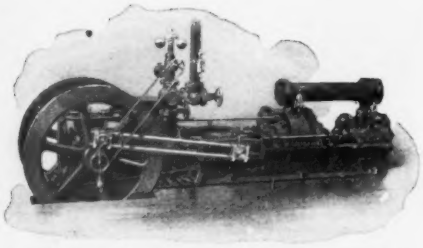

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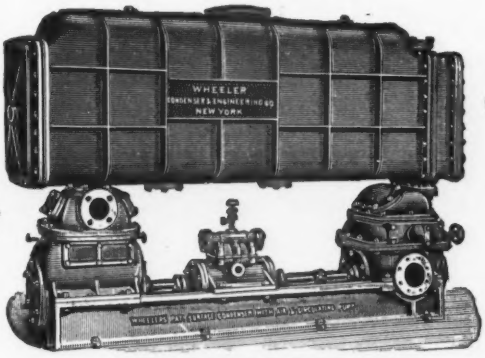

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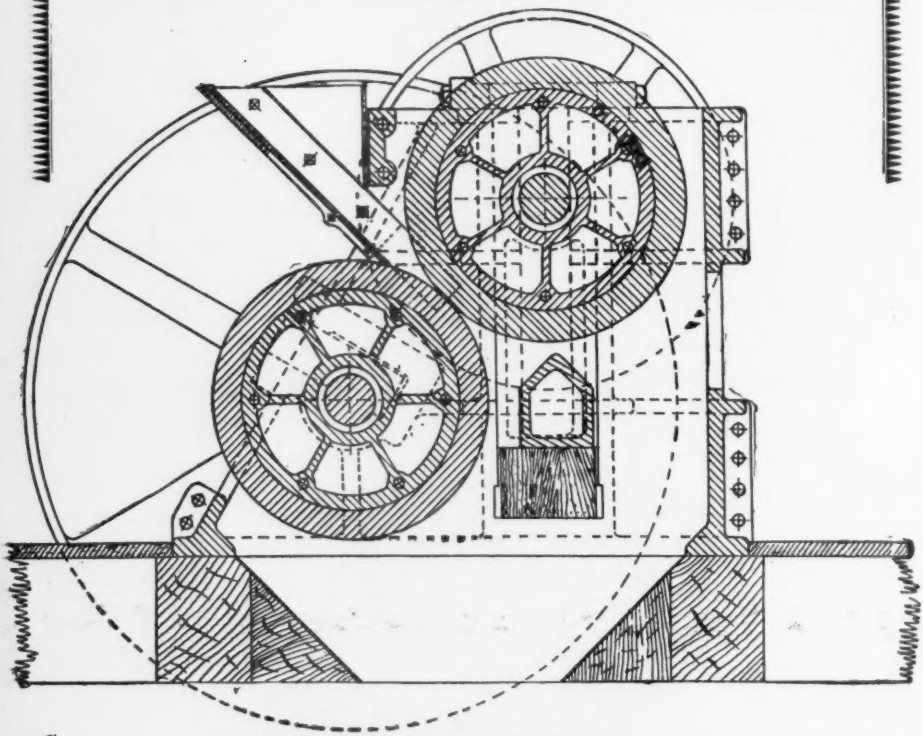

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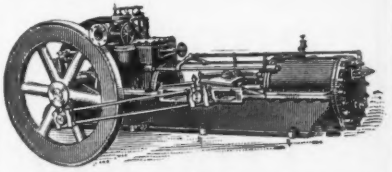

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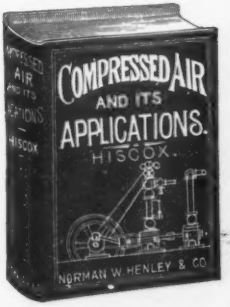

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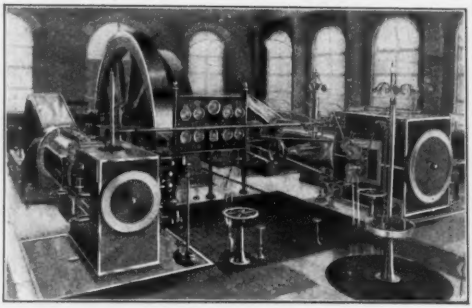

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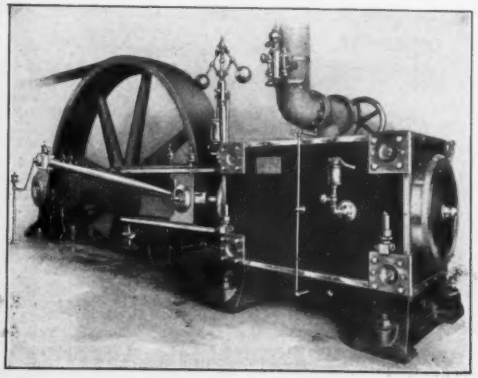

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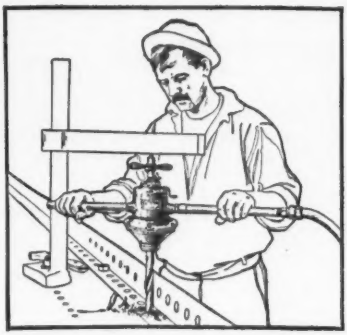

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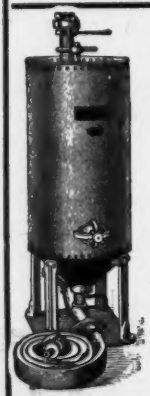

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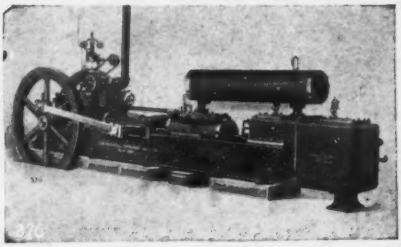

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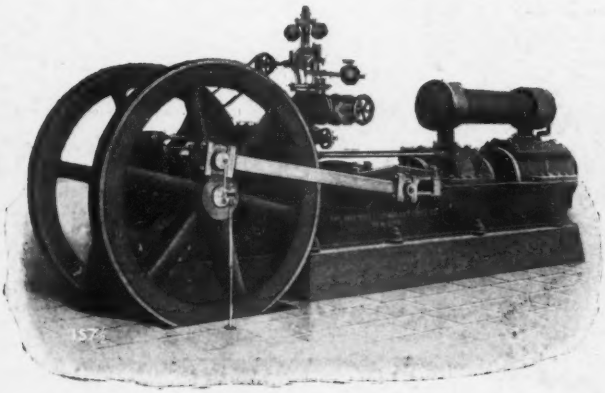

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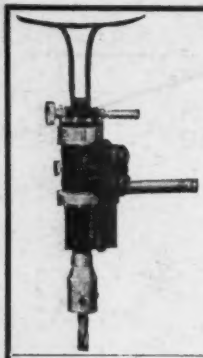

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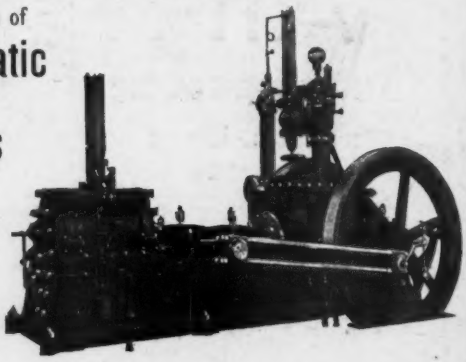

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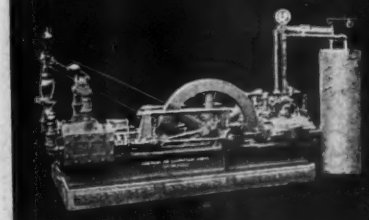

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